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## SHOT HARD HAT

PROJECT OFFICERS REPORT—PROJECT 3.6

# STATIC STRESS DETERMINATIONS


Leonard Obert, Project Officer

Applied Physics Research Laboratory
U.S. Bureau of Mines
College Park, Maryland



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# STATIC STRESS DETERMINATIONS

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ABSTRACT

Magnitudes of maximum and minimum stresses in the plane normal to the axis of several boreholes were determined in the rock adjacent to drifts at the Hard Hat experiment at the Nevada Test Site. Measurements were made both pre- and postshot. It is evident that the rock in the end of C-Drift was strongly disturbed by the Hard Hat event.

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## STATIC STRESS DETERMINATIONS

### INTRODUCTION

This investigation was performed for the Defense Atomic Support Agency, Department of Defense, and funded by the Atomic Energy Commission under Memorandum of Understanding AT(29-2)-914, dated 14 September 1959, as amended by Modification 8, dated 29 January 1962. The objectives of this investigation were:

1) To determine the stress concentration in the wall of the main Hard Hat drift at a site in the proximity of the shaft.
2) To determine the stress field in the Hard Hat granite at the site specified in (1). The stress field is defined as the stress in the rock before mining, or at a point sufficiently distant from any underground excavation to be unaffected by the excavation.
3) To determine the postshot stress concentration in the side walls and the east end of C-drift.
4) To analyze the results from both sites and to make a comparison of the pre-and postshot stress concentration in the C-drift site.

The stress determinations were made by the borehole deformation method developed by the Bureau of Mines and described in References 1 through 6.

### BACKGROUND

In the period August to October 1960, as a part of Lollipop Project 26-3, a previous stress determination was made in the east end of C-drift. The experimental phase of this project, which included both underground and laboratory measurements, was completed in October 1960, and a preliminary field report was sent to R.G. Preston, Lawrence

Radiation Laboratory (LRL) on 29 October 1960. A supplementary letter report was sent to R.G. Preston on 16 December 1960. This preliminary report and supplement included the field data and the stress determinations calculated therefrom. On the basis of these data, a number of conclusions were made regarding the rock stress at the site. A final report on this project was not made because of a suspension order, issued in January 1961, terminating any further work during that fiscal year.

Subsequently, during the summer of 1961, the site was reactivated by the Defense Atomic Support Agency, the primary purpose of study being the response of tunnel liners to shock loading from an underground explosion. This event was designated Shot Hard Hat of Operation Nougat.

Because a final analysis was not completed on the Lollipop project, and as this information was required in an analysis of the results from the present investigation, a reanalysis of the Lollipop data was made and the principal results included as a part of this report.

## DESCRIPTION OF TEST SITES

### Test Site 1

A plan of the Hard Hat excavation is shown in Figure 1, and a detail plan of Test Site 1 is shown in Figure 2.[1] The rock at this test site appeared to be unaffected by the Hard Hat shot. The granite was medium to coarse-grained and jointed, with a joint spacing ranging from about 12 to 24 inches. There were also fresh fractures in the wall rock, presumably caused by blasting. The stress relief holes drilled in

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[1] On the basis of information obtained at the test site, the axis of the main tunnel was taken as north and south. A Holmes and Narver drawing obtained at the time of the Lollipop investigation gave the bearing of the main tunnel as approximately N13°W. All angular data in this report are given with respect to the tunnel axis being taken as north and south.

the side walls indicated that the blasting fracture extended to a depth of 24 to 36 inches from the surface.

Test Site 2

A plan of Test Site 2 is shown in Figure 3. This test site, which was in the east end of C-drift, was in the light damage zone of the Hard Hat shot. Prior to the shot, the granite in this area showed a well developed system of jointing, with a joint spacing ranging from 3 to 12 inches. Also, the walls of the drift contained fresh fractures that were presumed to be caused by blasting. The stress relief holes drilled in the side walls showed this fracture to extend to a depth of 12 to 30 inches.

Postshot examination disclosed that from 12 to 24 inches of rock had spalled from the side walls and there was further evidence of fresh fracture in the new tunnel surfaces after this spall. A light spall occurred from the heading at the east end of the drift.

## THEORY AND EXPERIMENTAL PROCEDURE

Briefly, the experimental procedure for measuring the direction and magnitude of the minimum (T) and maximum (S) secondary principal stresses in the plane normal to the axis of the borehole, hereafter referred to as the secondary principal stresses,[2] was as follows:

1) A $1\frac{1}{2}$-inch diameter EX gage hole (pilot hole) was diamond drilled to the desired depth (usually between 10 and 20 feet).
2) A borehole deformation gage was placed in the hole at a point 4 inches from the collar of the hole and oriented to measure the vertical deformation in a horizontal hole, or the deformation in the north south direction in a vertical hole.

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[2] Secondary principal stresses are defined as the maximum and minimum normal stresses in any plane (except the principal planes). They lie in a direction in which the shear component is zero.

3) An initial deformation reading was taken.

4) The borehole gage was over-drilled to a depth such that further drilling produced no further change in the deformation. This depth was usually about 2 inches past the point of measurement.

5) A final deformation reading was taken. The borehole deformation is the difference between the initial and the final readings.

6) Next, the gage was moved into the hole 4 inches past the previous overcoring depth, oriented at 60° clockwise from the direction of the initial reading, and the overcoring procedure repeated.

7) The gage was again placed 4 inches past the previous overcoring depth, oriented at 60° counter-clockwise from the direction of the initial reading, and the overcoring procedure repeated.

8) This cycle was continued until a total depth of 24 inches had been drilled (which was the length of the overcoring core barrel). The core was then pulled, the gage reinserted in its next cyclic position, and the procedure continued.

9) To obtain the medium stress, the rosette readings were continued until a hole depth was reached such that no further change in the borehole deformation was produced.

10) The magnitude and direction of the secondary principal stresses in the plane normal to the axis of the borehole were calculated from the rosette data and the modulus of elasticity from Equations 1, 2, and 3.

$$S + T = \frac{E}{3d} (U_1 + U_2 + U_3) \qquad (1)$$

$$S - T = \frac{\sqrt{2}\,E}{6d} \left[ (U_1 - U_2)^2 + (U_2 - U_3)^2 + (U_3 + U_1)^2 \right]^{1/2} \qquad (2)$$

$$\tan 2\theta_1 = \frac{\sqrt{3}\,(U_3 - U_2)}{2U_1 - U_2 - U_3} \tag{3}$$

Where: S, T = maximum and minimum secondary principal stresses, respectively in the plane perpendicular to the axis of the borehole, psi.

E = modulus of elasticity of the rock, psi.

d = diameter of a borehole, inches.

$U_1$, $U_2$, $U_3$ = borehole deformation at a $60^\circ$ separation ($60^\circ$ deformation rosette), inches. U is positive for increasing diameter.

$\theta_1$ = angle from S to $U_1$, measured in the counter-clockwise direction, degrees.

if $U_2 > U_3$, $\theta_1$ is between $90^\circ$ and $180^\circ$;

if $U_2 < U_3$, $\theta_1$ is between $0^\circ$ and $90^\circ$;

if $U_2 = U_3$, and if, (a) $U_1 > U_2$, $\theta_1 = 0$;

(b) $U_1 < U_2$, $\theta_1 = 90^\circ$.

In performing the stress-relief drilling in this granite, a fraction of the measurements could not be completed. Areas in which the jointing was closely spaced (joint spacing less than 5 inches), a complete relief usually could not be affected.

At Site 1, three stress relief holes were drilled in mutually perpendicular directions. Two of the holes were drilled horizontally in the west side wall of the main drift, and one hole was drilled vertical in the floor (Figure 2). At Test Site 2, two horizontal holes were drilled in the end face of the drift, paralleling two holes drilled in the previous Lollipop test. Also, one horizontal hole was drilled in both the north and south face of the drift. Each of these holes paralleled a hole drilled in the previous Lollipop test.

Detail photographs of the cores from the holes at both sites are shown in Figures 4 thru 10. A photograph of the stress relief drill and borehole deformation measurement equipment used at Site 1 is shown in Figure 11. The stress-relief drill set-up at Site 2 is shown in Figure 12. The end face of C-drift, showing the two holes (right-hand holes) drilled for the Lollipop test in 1960, and the two holes (left-hand holes) drilled in this series of tests, are shown in Figure 13.

In the previous investigation, the modulus of elasticity, E, was determined by measuring the strain in a prism of rock cut from the stress relief core and subjected to uniaxial compression. An improved procedure for determining modulus of elasticity of stress-relief cores has been developed (Reference 7) and this procedure was used both at the Hardhat test site and in the laboratory for measuring the elastic constant of this rock. This method permits an evaluation of the anisotropy of the rock, and this determination was made for the granite from both Sites 1 and 2.

## RESULTS

The borehole deformation versus depth data from Holes 1, 2, and 3, Site 1, are given in Figures 14, 15, and 16. Note that in the first 40 inches in Hole 1, 17 inches in Hole 2, and 36 inches in Hole 3, no stress-relief measurements were obtained because the surface rock was too fractured from blasting. This fracture is evident in the photographs of these cores, Figures 4, 5, and 6. About the same depth of fracture was present at Site 2, although in Holes 2 and 3, an estimated 18 to 24 inches of original drift wall was removed by the Hard Hat shot.

The modulus of elasticity measurements from the Site 1 core are given in Table 1. These measurements were made by the biaxial method at 45$^{\circ}$ angular increments radial to the axis of the core to ascertain whether or not the granite was istropic.

The corresponding modulus of elasticity results from the Site 2 core are given in Table 2.

## DISCUSSION AND CONCLUSIONS

### Site 1

The calculated secondary principal stress versus depth results for Holes 1, 2, and 3, Site 1, are given in Figures 17, 18, and 19. In these figures the direction of the maximum (S) and minimum (T) stresses are indicated by the arrows at the top of the figure. These arrows give the direction of S and T in the plane perpendicular to the axis of the holes, as seen looking into the hole.

As the modulus of elasticity of the rock was virtually independent of direction, that is, as the rock was virtually isotropic, and also independent of the place where the rock was sampled, an average value of E of $8.91 \times 10^6$ psi was used in all Site 1 stress calculations.

The following conclusions were drawn from the results obtained in Hole 1, Figure 17:

1) No deformation measurement could be obtained between the collar of the hole and a depth of 40 inches because of blasting fracture, see Figures 4a and 4b. However, throughout the remainder of the hole, the rock was comparatively solid, except for one short shear zone at 10 feet, Figure 4f.
2) The maximum stress, S, at a depth of 40 inches was 4,000 psi. Between 40 and 150 inches, two maxima were measured, both of which were over 5,000 psi. The two peak stresses probably resulted from jointing in the rock. The low initial value was presumed to be due to a near-surface stress relaxation. This erratic near-surface behavior is characteristic of fractured or jointed rock.
3) The stress from 150 to the end of the hole (210 inches) was relatively constant and averaged approximately 1,800 psi, a value about twice that calculated on the basis of a gravity stress field.

4) The direction of the secondary principal stresses remained almost constant over the length of the hole, and S was about $30^{o}$ from the vertical.

5) The value of T averaged less than one-half of S, which could result from a complete lateral constraint and a Poisson's ratio of 0.33.

The results from Hole 2, Figure 18 show:

1) No deformation measurements could be obtained between the collar of the hole and a depth of 17 inches because of blasting fracture. This fracture is shown in Figure 5a. However, the rock was comparatively solid throughout the remainder of the hole.

2) The maximum stress, S, varied between 1,050 and 1,600 psi from a depth of 24 to 66 inches. This zone was apparently stress relaxed. From 66 to 116 inches, S and T went through a maximum (S= 3,000 psi maximum). From 116 to 208 inches the S varied between 750 to 1,700 psi but leveled off near 1,500 psi in the end of the hole. This value was about 300 psi less than the average maximum stress in the end of Hole 1.

3) The direction of the secondary principal stresses was relatively constant. and S was inclined at an angle of about $30^{o}$ with respect to the vertical.

4) Near the end of Hole 2, T was equal to about two-thirds of S, which for a complete lateral constraint would correspond to a Poisson's ratio of 0.4.

The results from Hole 3, Figure 19, show:

1) No deformation measurement could be obtained between the collar of the hole and a depth of 32 inches because of blasting fracture, Figure 6a.

2) Starting at 32 inches to the end of the hole the stress distributions were almost normal, that is, in agreement with theory. The maximum stress, S, was 2,600 psi at a depth of 32 inches and decreased to about 900 psi at a depth of 90 inches. From 90 inches to the end of the hole, S and T averaged about 850 psi and 750 psi, respectively. These values are comparable with the near horizontal values (T values) obtained in Holes 1 and 2.
3) The direction of the maximum stress, S, was approximately east and west, although the direction was more erratic than in Holes 1 and 2.
4) From 90 inches to the end of the hole, T was about three-fourths of S.

In summary, the results from Site 1 indicate that:

1) The rock was fractured to a depth from 24 to 42 inches. This fracture was probably caused by blasting.
2) Except for Hole 3, the rock stress was relaxed near the surface of the opening, an effect which may be due to the combined action of blasting and jointing.
3) The maximum stress in the three Site 1 holes varied from 2,500 psi to 5,600 psi. The stress concentration for Holes 1, 2, and 3 was approximately 3, 2, and 3, respectively.
4) The magnitude of the maximum stress, S, near the end of Holes 1 and 2 averaged about 1,650 psi, which is substantially larger than the maximum calculated gravity stress, which would be about 1,000 psi. Hence, a tectonic stress is indicated. Also, the direction of the maximum rock stress is not vertical as would be expected for a gravitational stress field.

5) The magnitude and direction and S and T measured in Hole 3 show an approximate agreement with the T values in Holes 1 and 2.

6) In Holes 1 and 2, S was one-third to one-half of T.

Site 2

The calculated secondary principal stress versus depth results for Holes 1, 2, 3, and 4, Site 2, are given in Figures 20, 21, 22, and 23. The direction arrows for S and T are oriented as in the Site 1 figures.

At Site 2, the granite was relatively isotropic and the modulus of elasticity was independent of the place where the rock was sampled. The average value of E was $9.73 \times 10^6$ psi, and the value was used in all Site 2 calculations.

The results from Hole 1, given in Figure 20 show:

1) The first 30 inches of the hole were fractured, Figure 7a, presumably from blasting. Also, a fractured zone occurred between 85 and 109 inches, Figure 7c. The extent of the fracture in this hole limited the number of deformation measurements.

2) The maximum stress (S = 2,150 psi) occurred at a depth of 30 inches, and S decreased to a minimum of 750 psi at 114 inches.

3) The stress at the end of Hole 1 did not level off, but further measurement was discontinued because of drilling difficulty.

4) The direction of the secondary principal stresses was relatively constant and inclined at an angle of $60^{\circ}$ from the vertical.

The results from Hole 2, given in Figure 21, show:

1) That near surface fracture persisted to a depth of 30 inches, see Figure 8a. Also, the core was fractured near the end of the hole, Figure 8d.

2) No stress concentration was indicated in this hole. The value of S averaged about 1,100 psi, and T averaged less than 50 percent of S.

3) The direction of S and T rotated about 90° between a depth of 40 and 120 inches.

4) There was no similarity in the stress distribution in Hole 1 and Hole 2, although these holes were only 16 inches apart, as shown in Figure 13.

Only a very limited result was obtained from Hole 3 (Figure 22) because of the heavy fracture throughout the hole, see Figures 9a through 9d. However, a near surface stress concentration was indicated, see Figure 22, with a maximum value of S of 2,000 psi at 48 inches, and the stress leveled off near the end of the hole (S = 750 psi, T = 350 psi).

The results from Hole 4, given in Figure 23 show:

1) The rock was heavily fractured to a depth of 24 inches, probably from blasting (Figure 10a). Also, there was a fracture zone near the end of the hole.

2) From a depth of 24 to 42 inches, the rock stress was almost hydrostatic, that is, S = T, and the magnitude of S and T indicated a near-surface stress relaxation. From 42 to 96 inches, S and T went through a weak maximum (peak at 72 inches) with S = 1,350 psi (maximum). From 96 to 120, S leveled off at 1,125 psi.

3) From 70 to 120 inches the direction S was inclined 20° to 25° from the horizontal.

Comparison of Lollipop and Hard Hat results from Site 2

The Lollipop results are given in Figures 24 through 29. Note in Figure 24 that the borehole deformation versus depth measurements from Holes E and F indicated a good reproducibility, and the calculated secondary principal stress, given in Figures 27 and 28, showed a corresponding hole-to-hole agreement. Thus, it can be concluded that the jointing in the rock did not strongly affect the stress pattern in a measurement spacing of 16 inches. However, in either Hole E or F, the magnitude of the stresses S and T varied erratically with the depth, which is characteristic of fractured rock. If the Lollipop data from Holes E and F are compared with the Hard Hat results from Holes 1 and 2, Site 2, which were parallel to, and within 16 inches of Holes E and F, it is evident that the rock in the end of C-drift was strongly disturbed by the Hard Hat shot; neither the pre- or postshot magnitude nor direction of S and T showed any agreement.

Correspondingly, if the Lollipop preshot data for Holes B and C are compared with the Hard Hat results from Holes 4 and 3 respectively, there is virtually no similarity between either the magnitude or direction of S and T.

No Hard Hat measurement was taken in the floor of C-drift to compare with the Lollipop results from Holes G and H, because the floor appeared to be too fractured to permit stress-relief drilling.

Thus, a comparison of the Lollipop and Hard Hat measurements indicated that the granite in both the end and side-walls of C-drift had been disturbed to a depth of at least 10 feet.

TABLE 1 MODULUS OF ELASTICITY OF STRESS RELIEF CORES, SITE NO. 1 (NEAR SHAFT)

| Hole No. 1 | Depth Inches | Orientation degrees* | $E \times 10^6$ psi | Average $E \times 10^6$ psi |
|---|---|---|---|---|
| 1 | 60 | 0 | 8.81 | |
| | | -45 | 8.61 | |
| | | -90 | 8.02 | 8.40 |
| | | +45 | 8.10 | |
| 1 | 144 | 0 | 8.83 | |
| | | -45 | 9.04 | |
| | | -90 | 8.92 | 9.00 |
| | | +45 | 9.28 | |
| 2 | 60 | 0 | 9.24 | |
| | | -45 | 8.87 | 8.97 |
| | | -90 | 8.82 | |
| | | +45 | - | |
| 2 | 120 | 0 | 8.89 | |
| | | -45 | 9.10 | 9.07 |
| | | -90 | 9.24 | |
| | | +45 | -- | |
| 3 | 56 | 0 | 8.82 | |
| | | -45 | 9.09 | |
| | | -90 | 9.45 | 9.10 |
| | | +45 | 9.04 | |
| 3 | 144 | 0 | 8.82 | |
| | | -45 | 8.79 | 8.93 |
| | | -90 | 9.28 | |
| | | +45 | 8.84 | |

$\Sigma$ average = $8.91 \times 10^6$ psi

Variance = $\sigma^2$ = 0.105

Standard Deviation = $\sigma$ = 0.326

*In horizontal holes with respect to vertical. In vertical holes with respect to N-S.

TABLE 2 MODULUS OF ELASTICITY OF STRESS RELIEF CORES, SITE NO. 2 (EAST END OF C-DRIFT)

| Hole No. | Depth Inches* | Orientation Degrees* | $E \times 10^6$ psi | $E \times 10^6$ psi |
|---|---|---|---|---|
| 1 | 50 | 0 | 9.73 | |
| | | -45 | 9.80 | |
| | | -90 | 9.75 | 9.67 |
| | | +45 | 9.40 | |
| 2 | 120 | 0 | 9.73 | |
| | | -45 | 9.88 | 9.81 |
| | | -90 | 9.90 | |
| | | +45 | 9.75 | |
| 3 | 79 | 0 | 9.80 | |
| | | -45 | 10.42 | |
| | | -90 | 10.03 | 10.00 |
| | | +45 | 9.75 | |
| 4 | 51 | 0 | 9.48 | |
| | | -45 | 9.51 | |
| | | -90 | 9.48 | 9.52 |
| | | +45 | 9.54 | |
| 4 | 103 | 0 | 10.04 | |
| | | -45 | 10.43 | |
| | | -90 | 9.75 | 9.99 |
| | | +45 | 9.75 | |
| 4 | 121 | 0 | 9.20 | |
| | | -45 | 9.40 | |
| | | -90 | 9.49 | 9.39 |
| | | +45 | 9.49 | |

$\Sigma$ Average $= 9.73 \times 10^6$ psi

Variance $= \sigma^2 = 0.0792$

Standard Deviation $= \sigma = 0.282$

*with respect to vertical

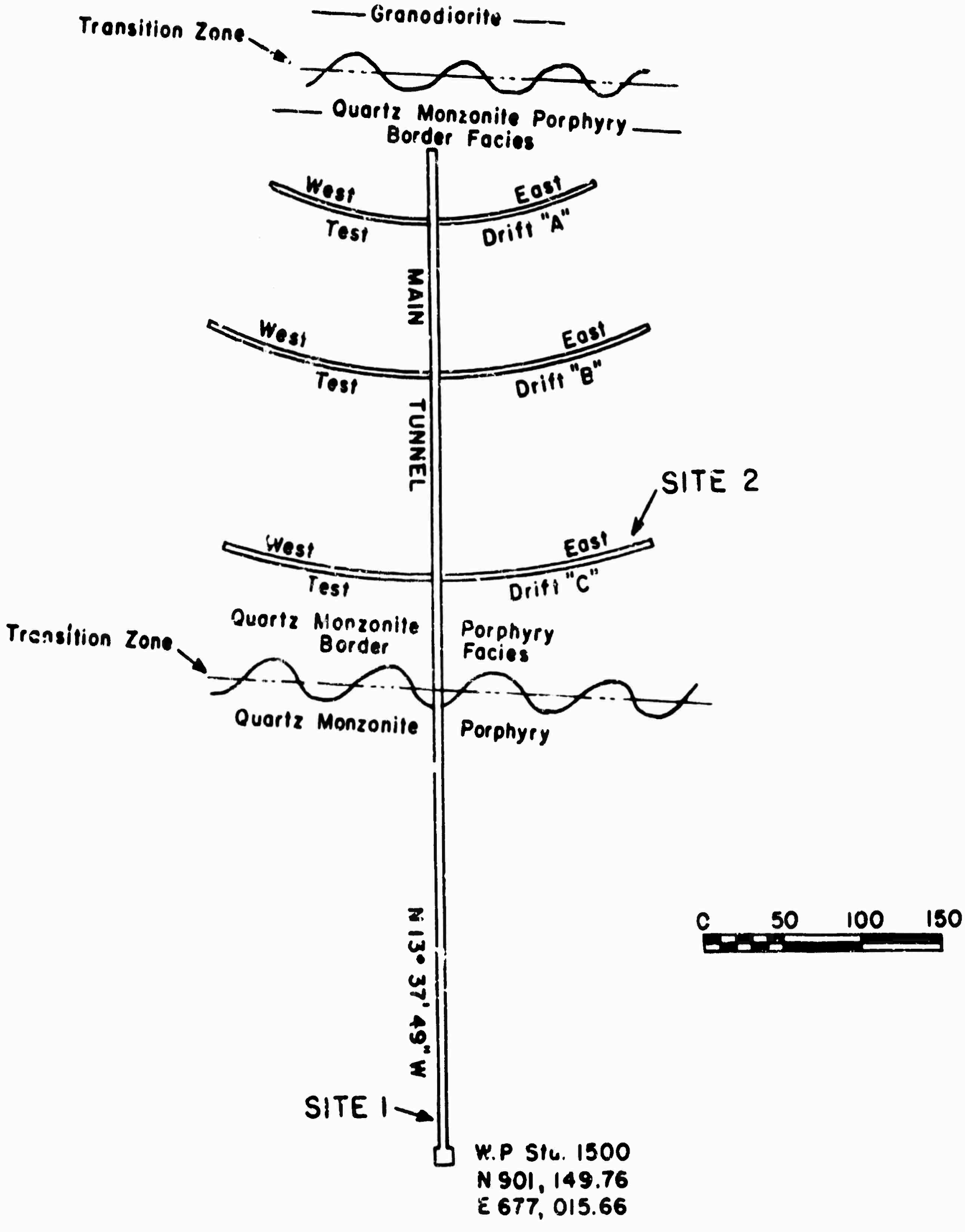


Figure 1 Plan of Hard Hat excavation.

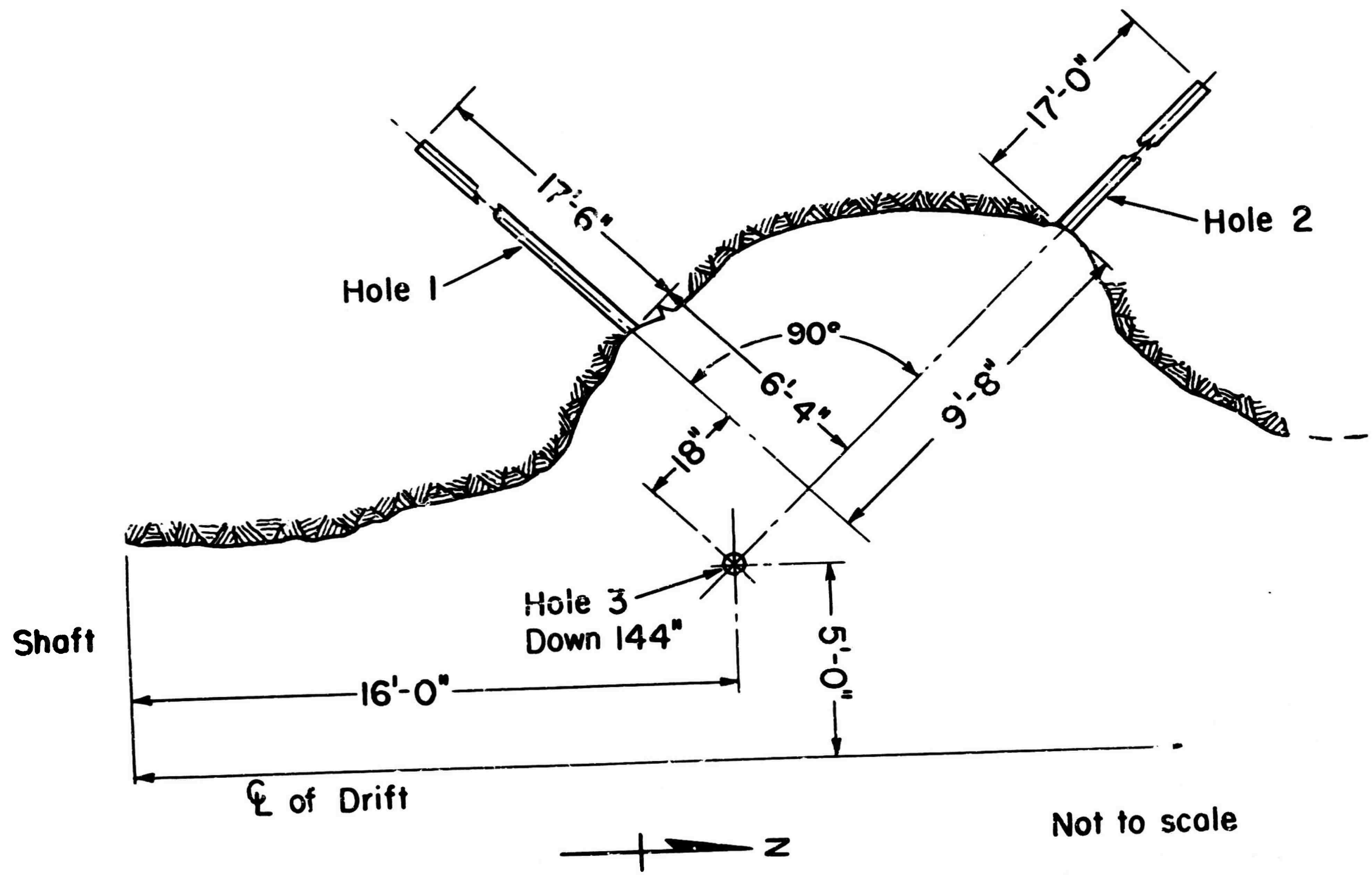


Figure 2  Plan, Site 1.

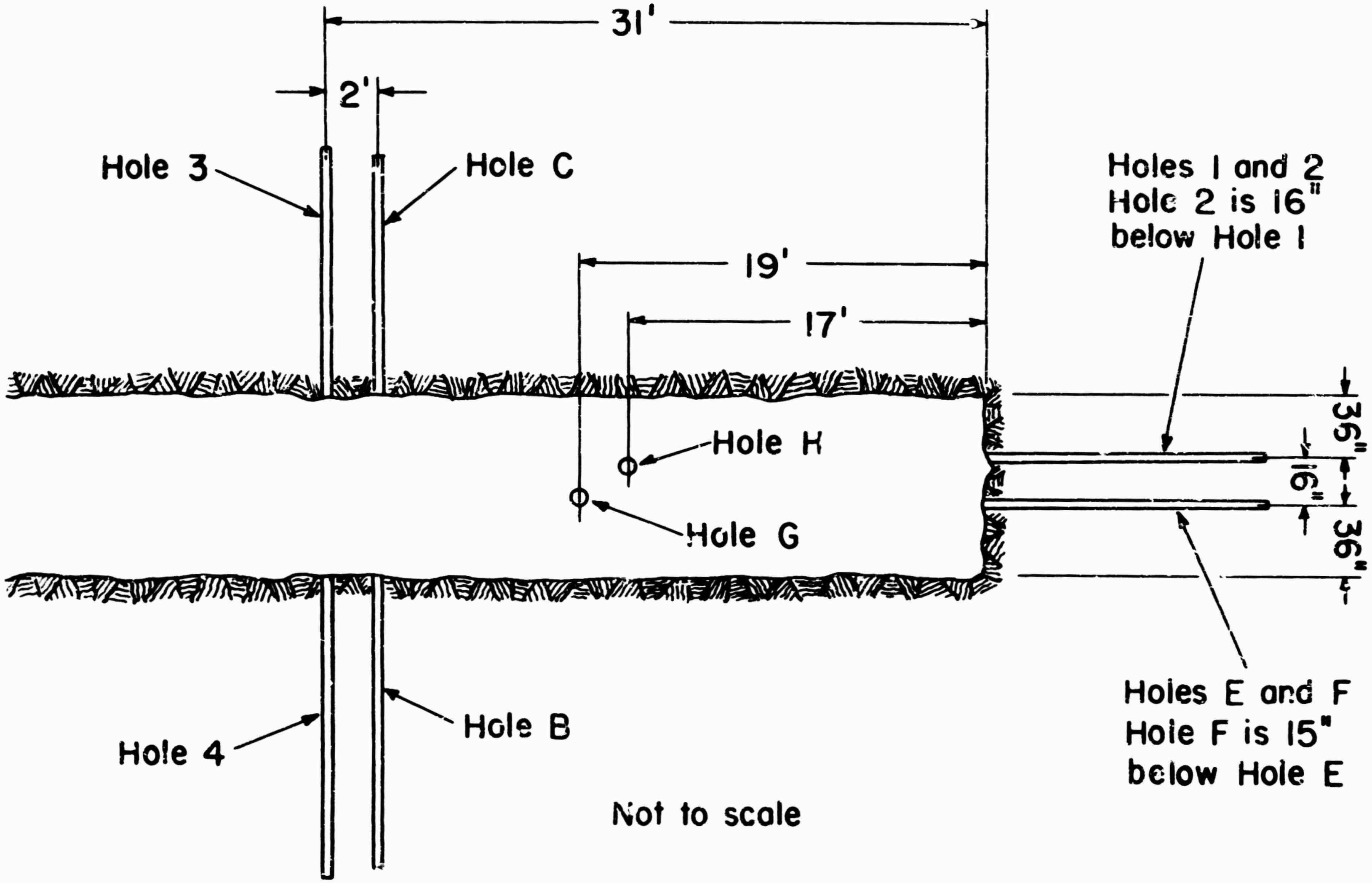


Figure 3 Plan, Site 2.


Figure 4a Site 1, Hole 1, interval 0 to 2 feet 6 inches, core sampling. (DASA 394-01-NTS-62)


Figure 4b Site 1, Hole 1, interval 2 feet 6 inches to 4 feet 6 inches, core sampling. (DASA 394-02-NTS-62)

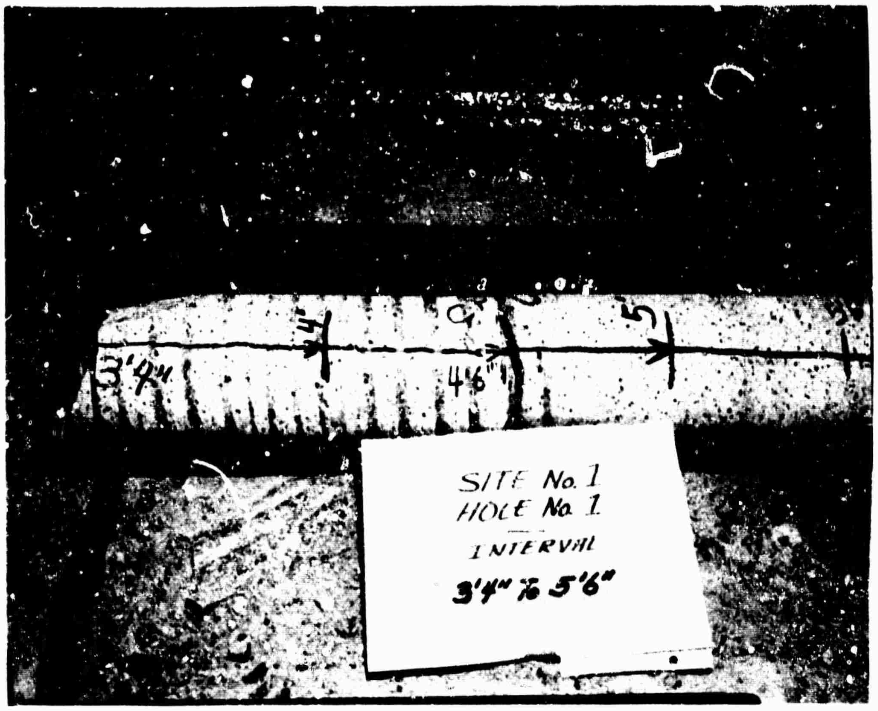


Figure 4c Site 1, Hole 1, interval 3 feet 4 inches to 5 feet 6 inches, core sampling. (DASA 394-03-NTS-62)

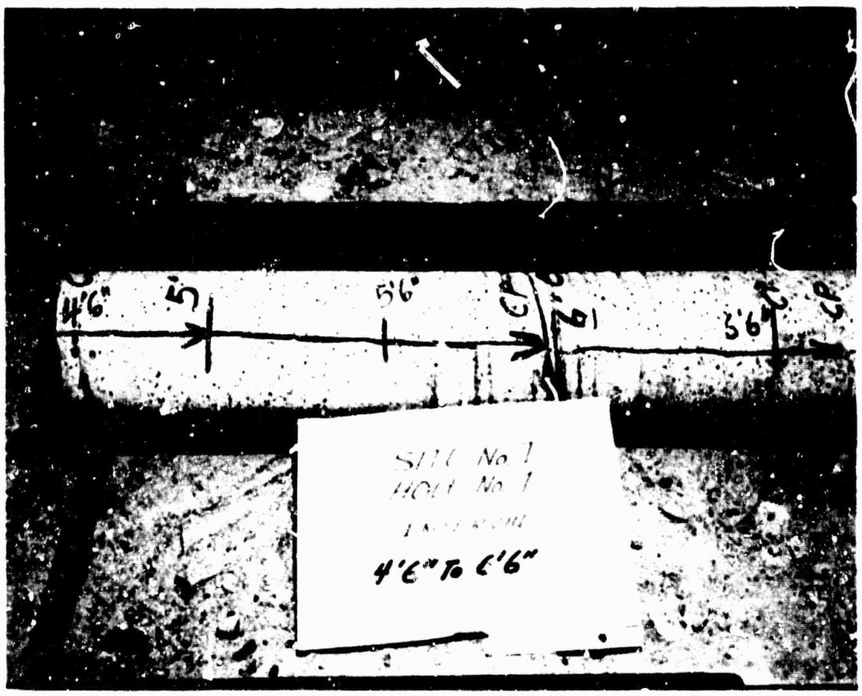


Figure 4d Site 1, Hole 1, interval 4 feet 6 inches to 6 feet 6 inches, core sampling. (DASA 394-04-NTS-62)


Figure 4e Site 1, Hole 1, interval 6 to 9 feet, core sampling. (DASA 402-02-NTS-62)

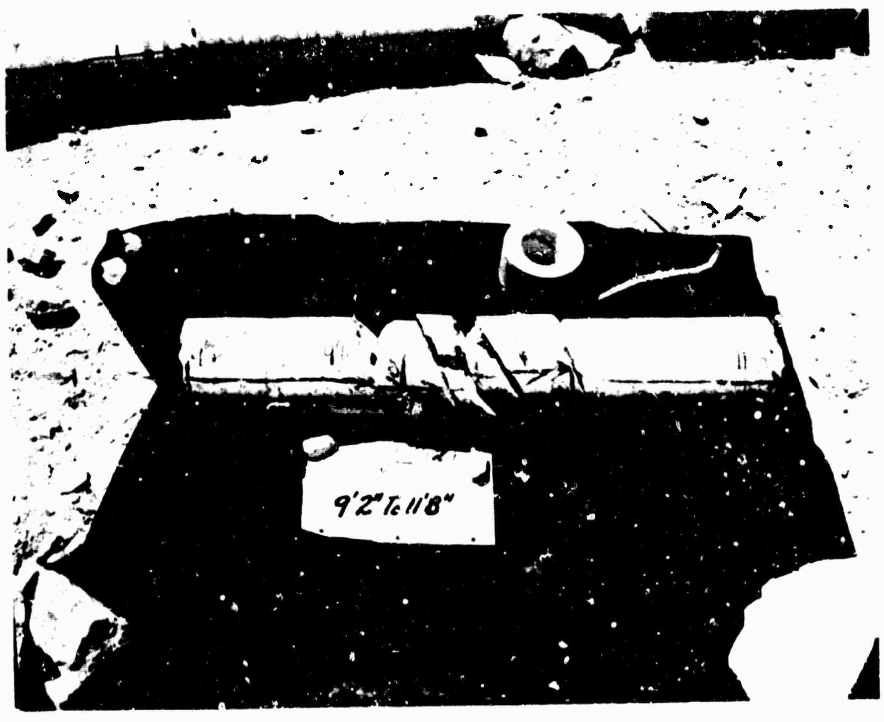


Figure 4f Site 1, Hole 1, interval 9 feet 2 inches to 11 feet 8 inches, core sampling. (DASA 402-04-NTS-62)


Figure 4g Site 1, Hole 1, interval 11 feet 8 inches to 14 feet, core sampling. (DASA 394-05-NTS-62)


Figure 4h Site 1, Hole 1, interval 12 feet 9 inches to 15 feet, core sampling. (DASA 394-06-NTS-62)


Figure 4i Site 1, Hole 1, interval 14 feet 5 inches to 16 feet 6 inches, core sampling. (DASA 394-07-NTS-62)


Figure 4j Site 1, Hole 1. interval 16 feet 6 inches to 18 feet 2 inches, core sampling. (DASA 394-09-NTS-62)


Figure 5a  Site 1,  Hole 2, interval 0 to 3 feet, core sampling.  (DASA 394-18-NTS-62)

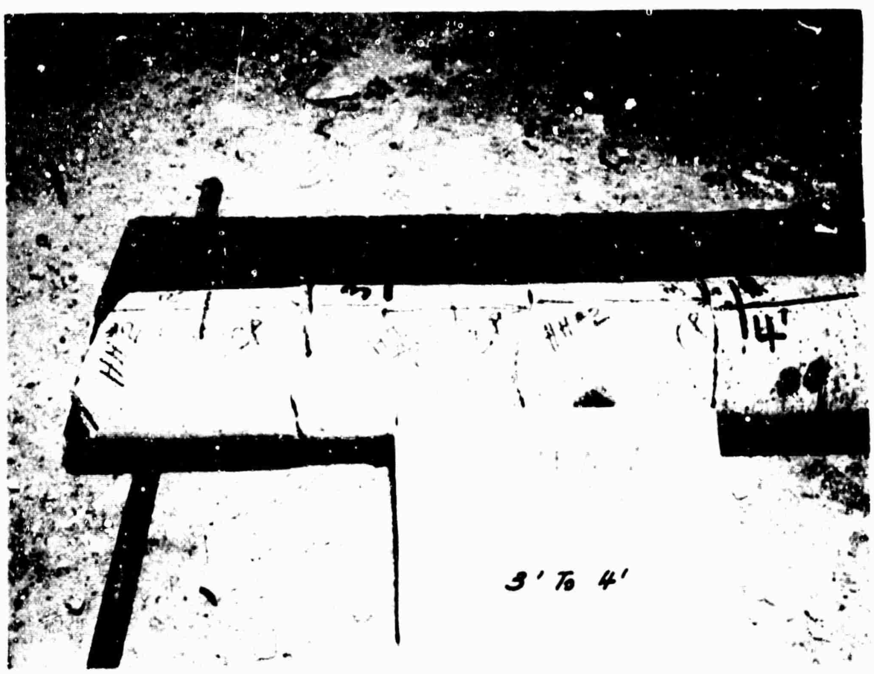


Figure 5b  Site 1, Hole 2, interval 3 to  4 feet, core sampling.  (DASA 394-17-NTS-62)


Figure 5c Site 1, Hole 2, interval 4 to 6 feet, core sampling. (DASA 394-17A-NTS-62)

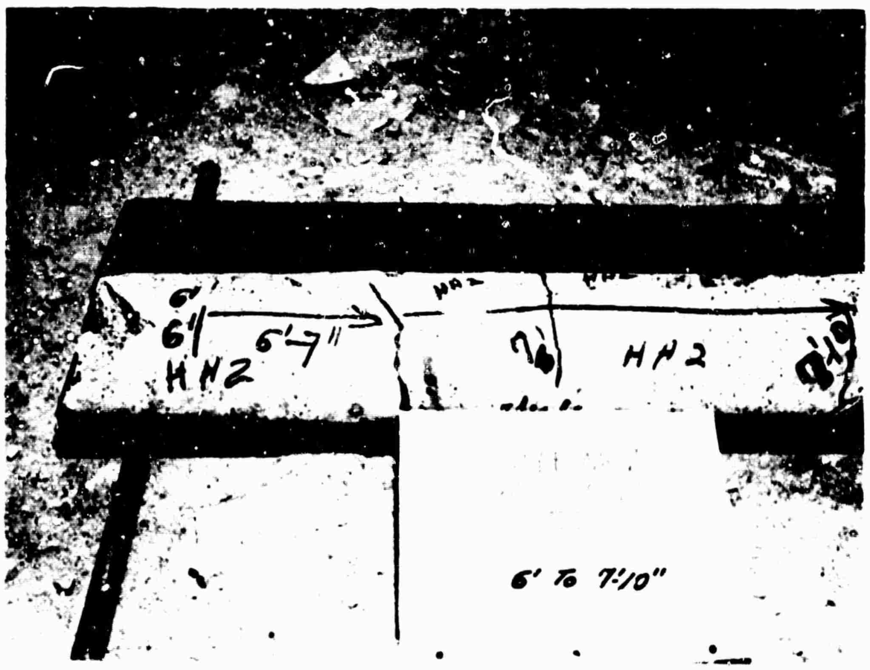


Figure 5d Site 1, Hole 2, interval 6 feet to 7 feet 10 inches, core sampling. (DASA 394-16-NTS-62)

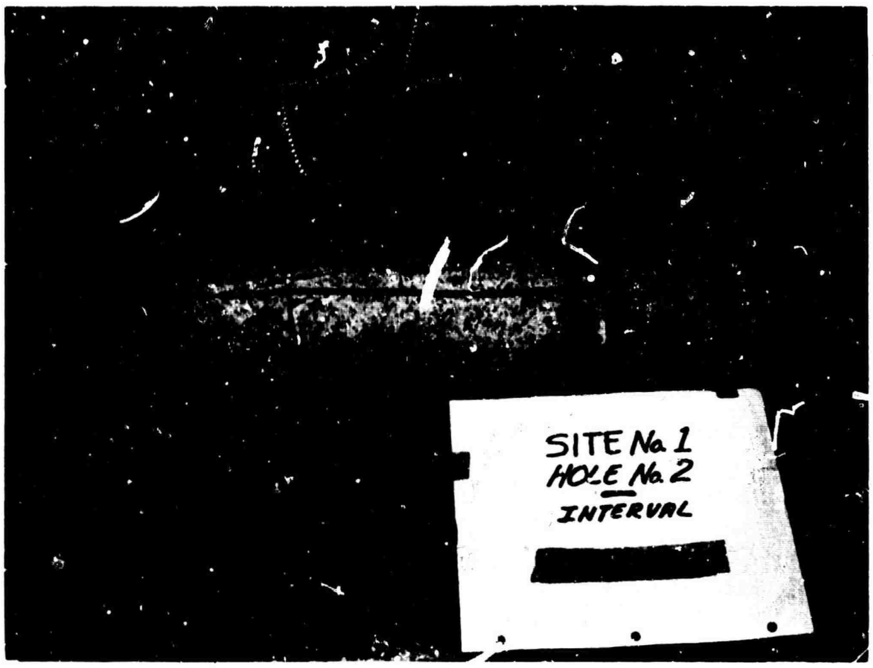


**Figure 5e Site 1, Hole 2, interval 7 feet to 8 feet 10 inches, core sampling. (DASA 394-15-NTS-62)**

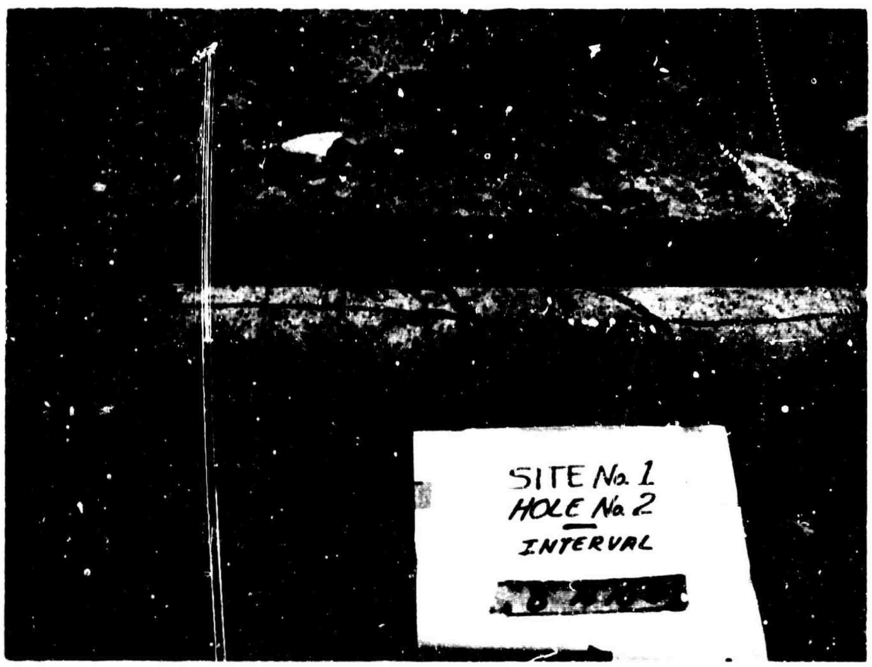


**Figure 5f Site 1, Hole 2, interval 8 to 10 feet, core sampling. (DASA 394-14-NTS-62)**

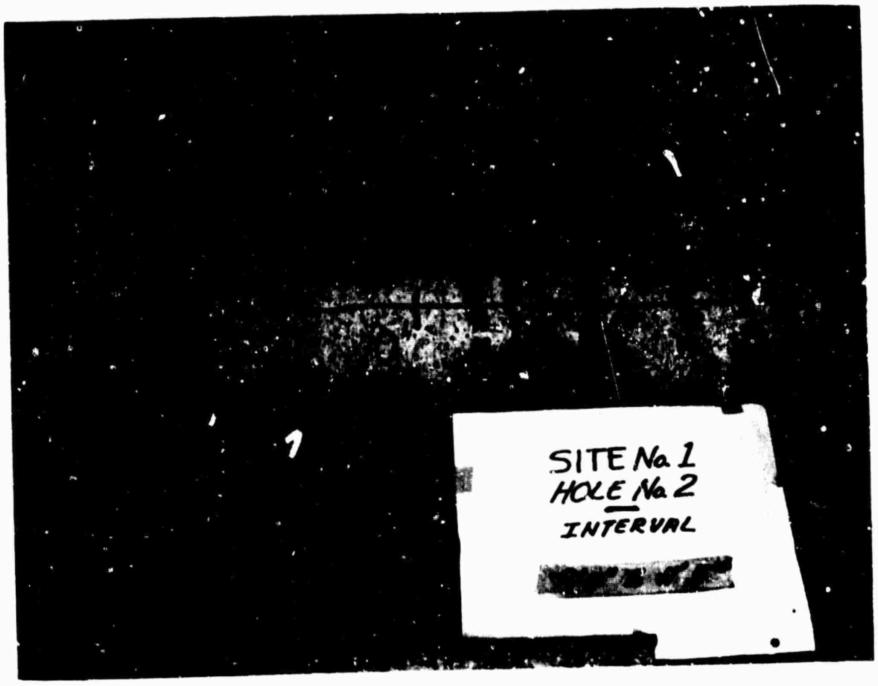


Figure 5g Site 1, Hole 2, interval 9 feet 4 inches to 11 feet 5 inches, core sampling. (DASA 394-19-NTS-62)


Figure 5h Site 1, Hole 2, interval 10 feet 5 inches to 13 feet 6 inches, core sampling. (DASA 394-13-NTS-62)

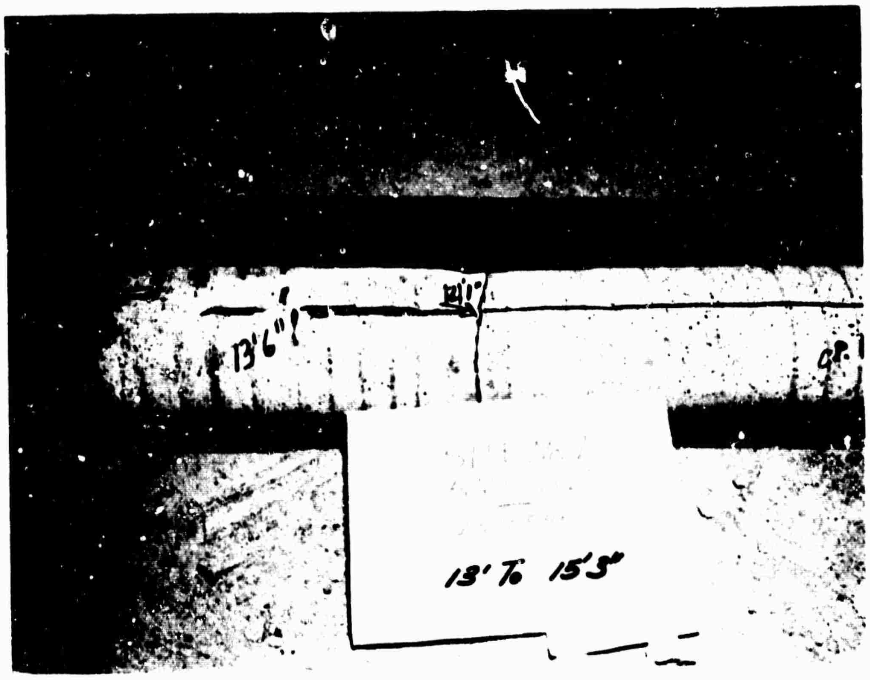


Figure 5i Site 1, Hole 2, interval 13 feet to 15 feet 3 inches, core sampling. (DASA 394-12-NTS-62)

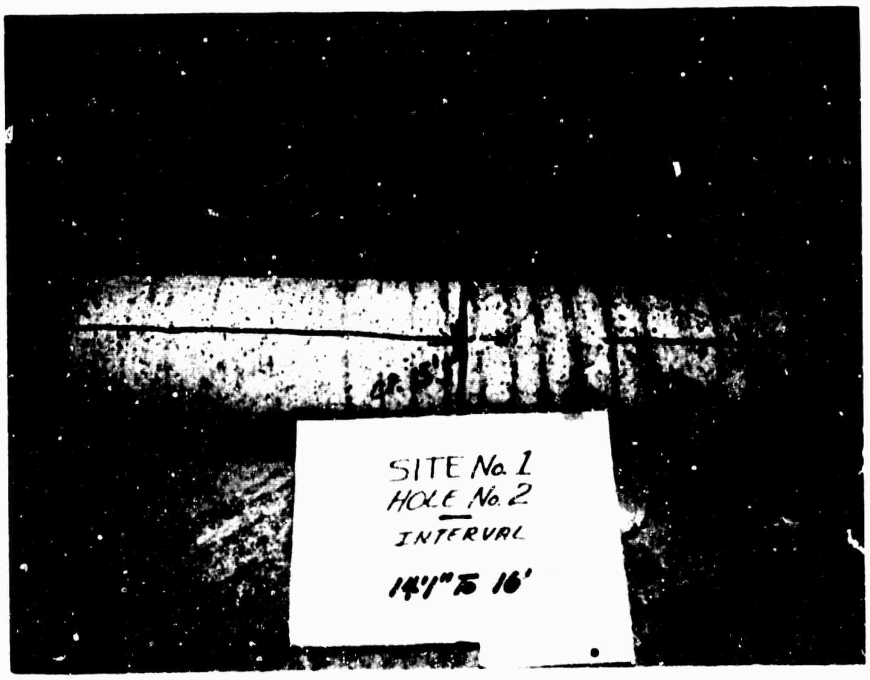


Figure 5j Site 1, Hole 2, interval 14 feet 1 inch to 16 feet, core sampling. (DASA 394-11-NTS-62)

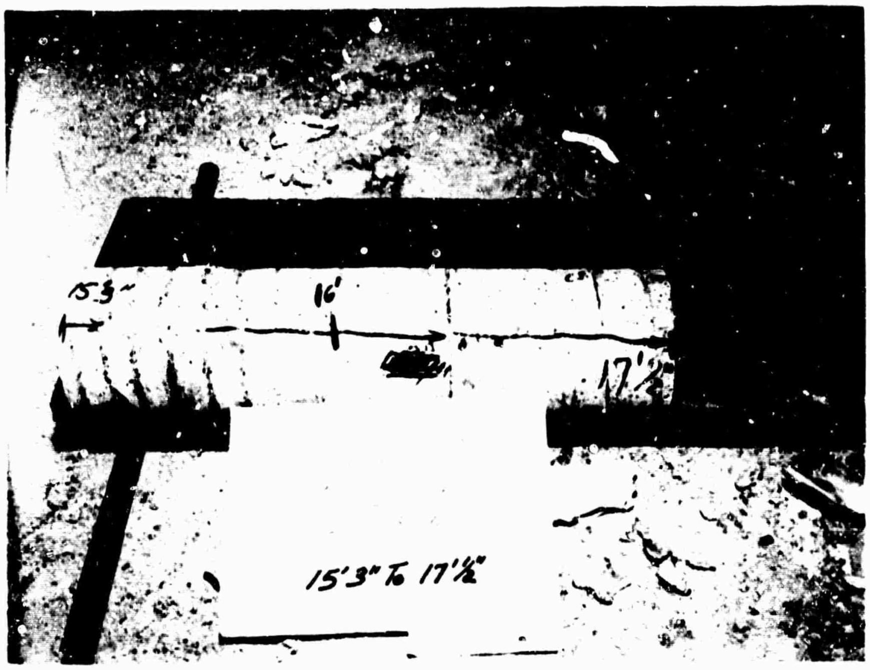


Figure 5k Site 1, Hole 2, interval 15 feet 3 inches to 17 feet ½ inch, core sampling. (DASA 394-10-NTS-62)


Figure 6a  Site 1, Hole 3, interval 0 feet to 26 inches, core sampling.  (DASA 435-03-NTS-62)

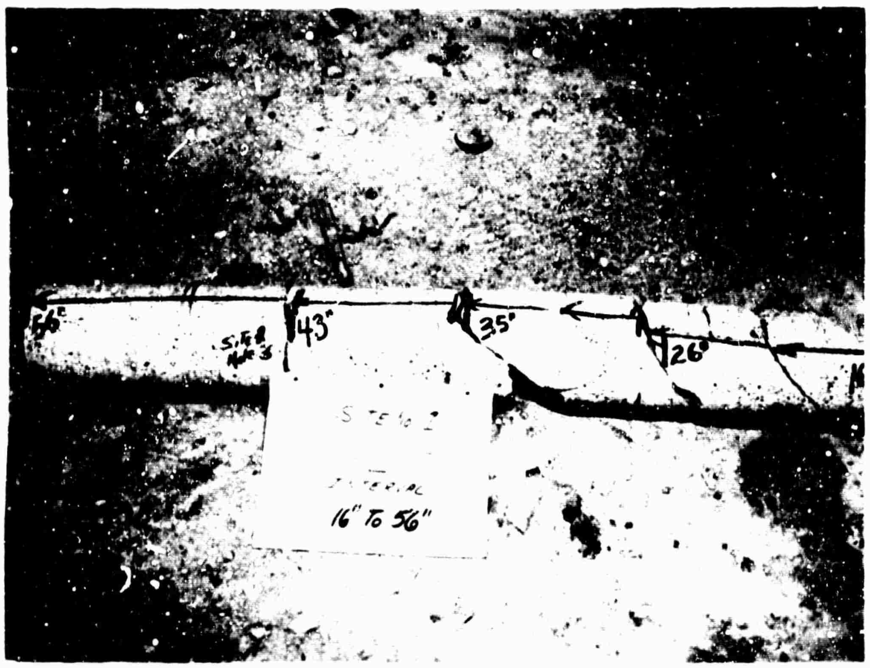


Figure 6b  Site 1. Hole 3, interval 16 to 56 inches, core sampling.  (DASA 435-02-NTS-62)

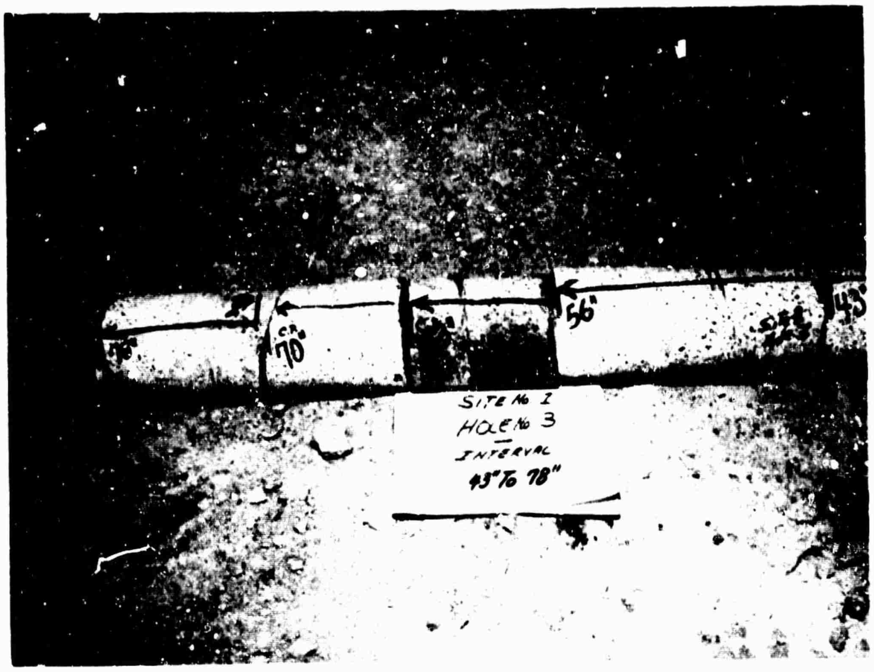


Figure 6c Site 1, Hole 3, interval 43 to 78 inches, core sampling. (DASA 435-06-NTS-62)


Figure 6d Site 1, Hole 3, interval 78 to 110 inches, core sampling. (DASA 435-05-NTS-62)

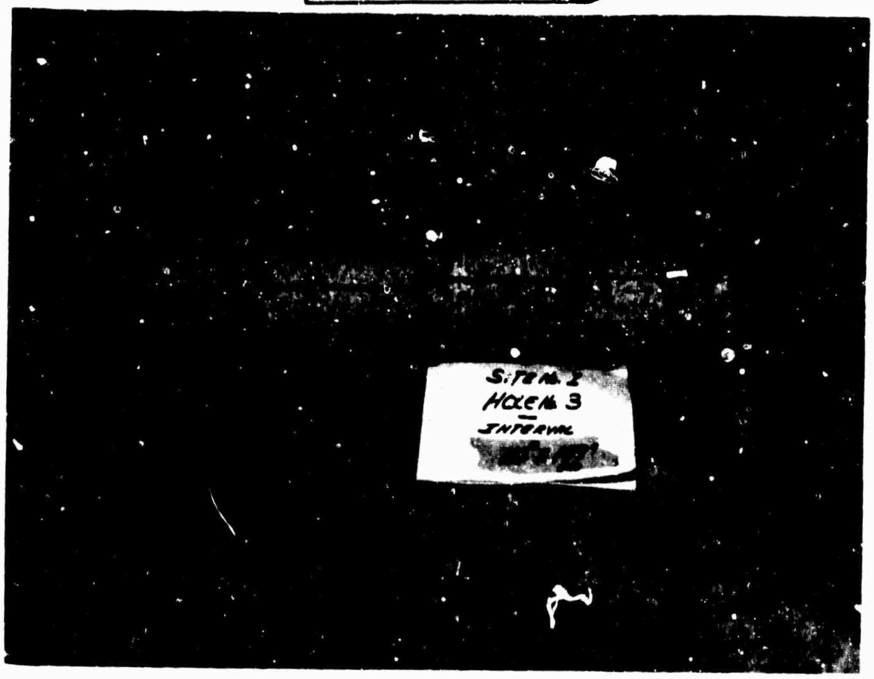


Figure 6e Site 1, Hole 3, interval 110 to 149 inches, core sampling. (DASA 435-01-NTS-62)

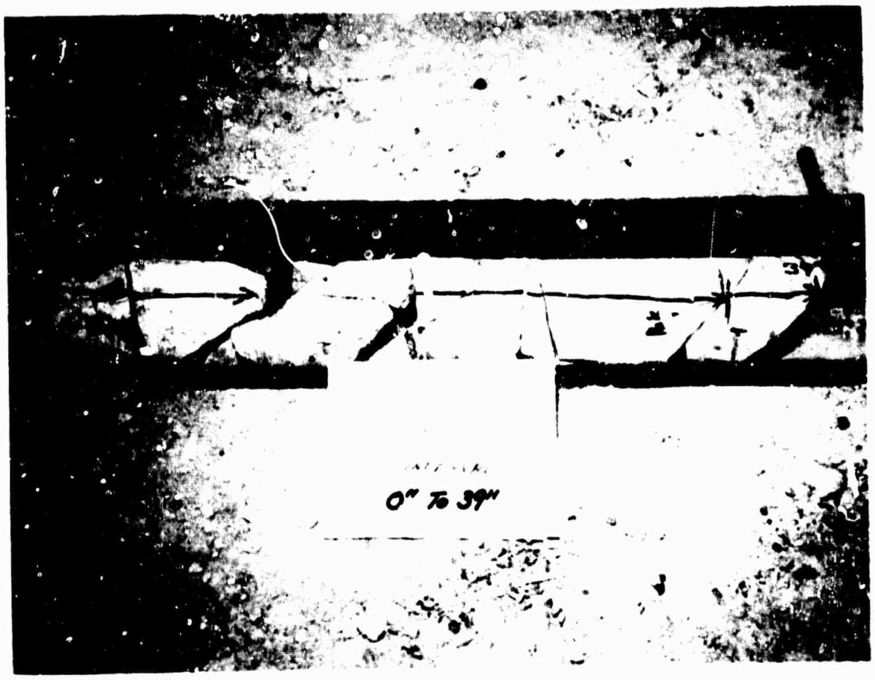


Figure 7a  Site 2, Hole 1, interval 0 to 39 inches, core sampling. (DASA 451-01-NTS-62)

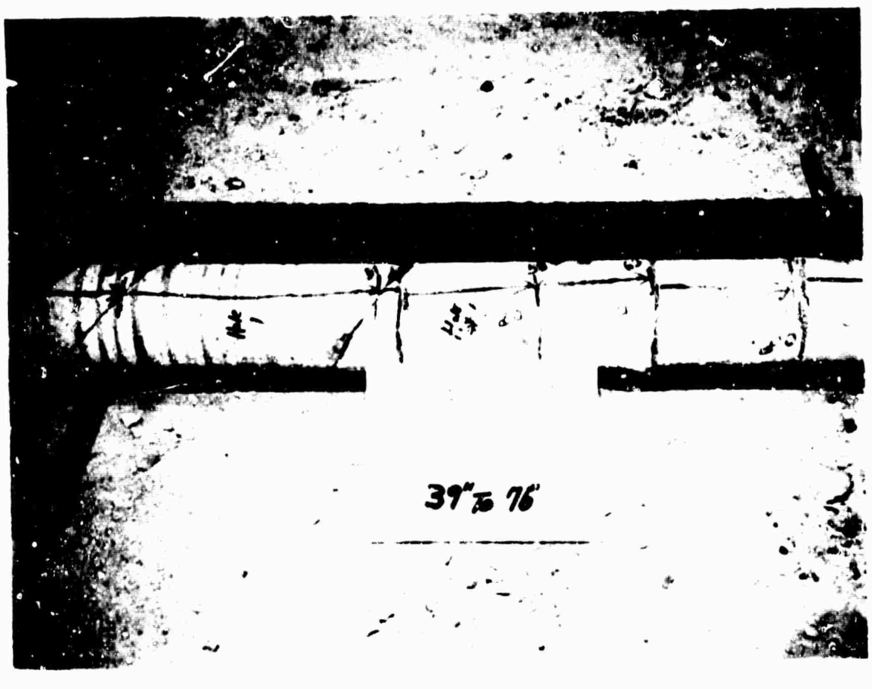


Figure 7b  Site 2, Hole 1, interval 39 to 76 inches, core sampling. (DASA 451-02-NTS-62)


Figure 7c Site 2, Hole 1, interval 76 to 109 inches, core sampling. (DASA 451-07-NTS-62)

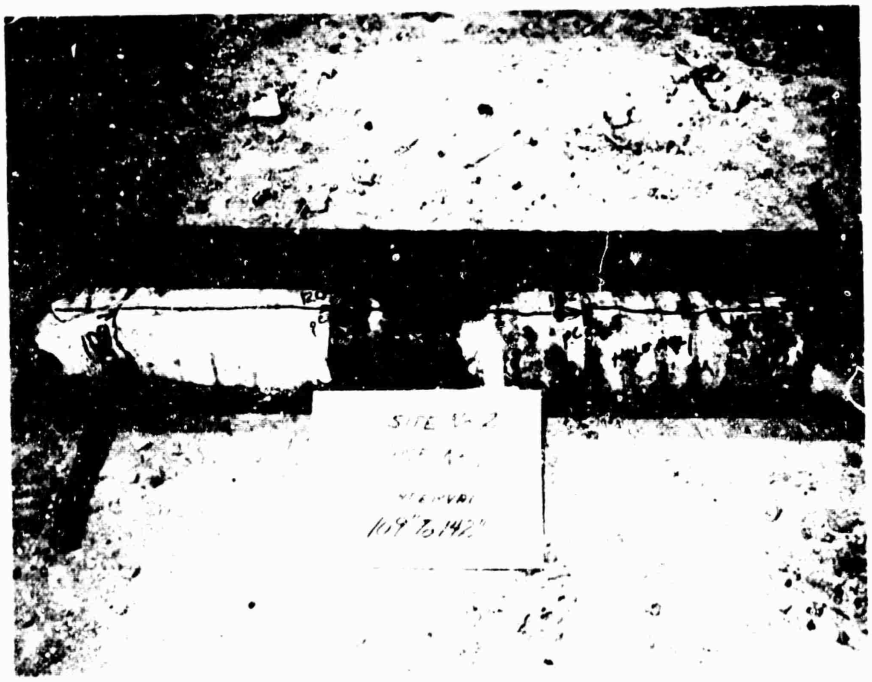

Figure 7d Site 2, Hole 1, interval 109 to 142 inches, core sampling. (DASA 451-06-NTS-62)

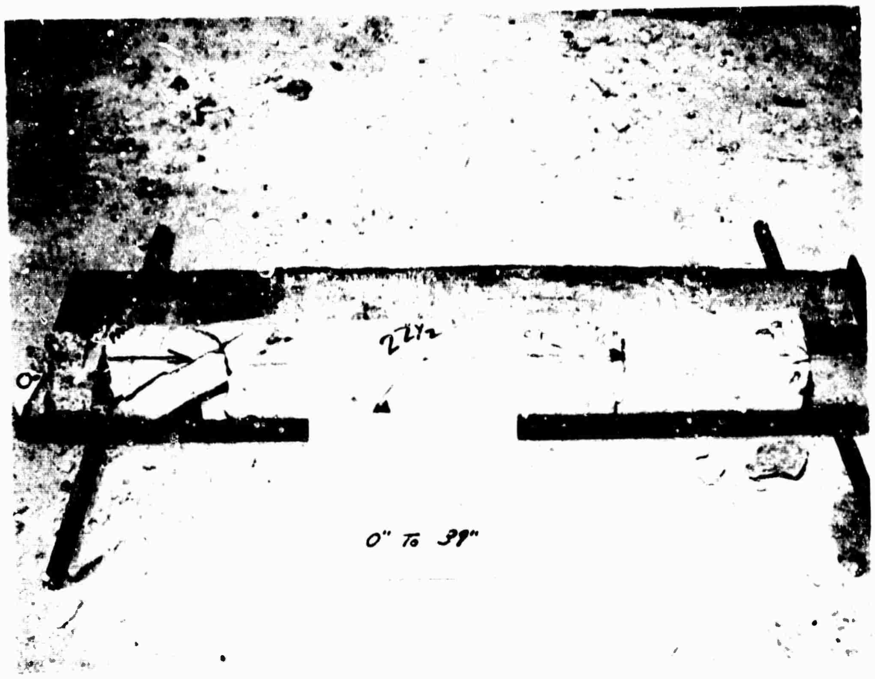


Figure 8a Site 2, Hole 2, interval 0 to 39 inches, core sampling. (DASA 451-16-NTS-62)

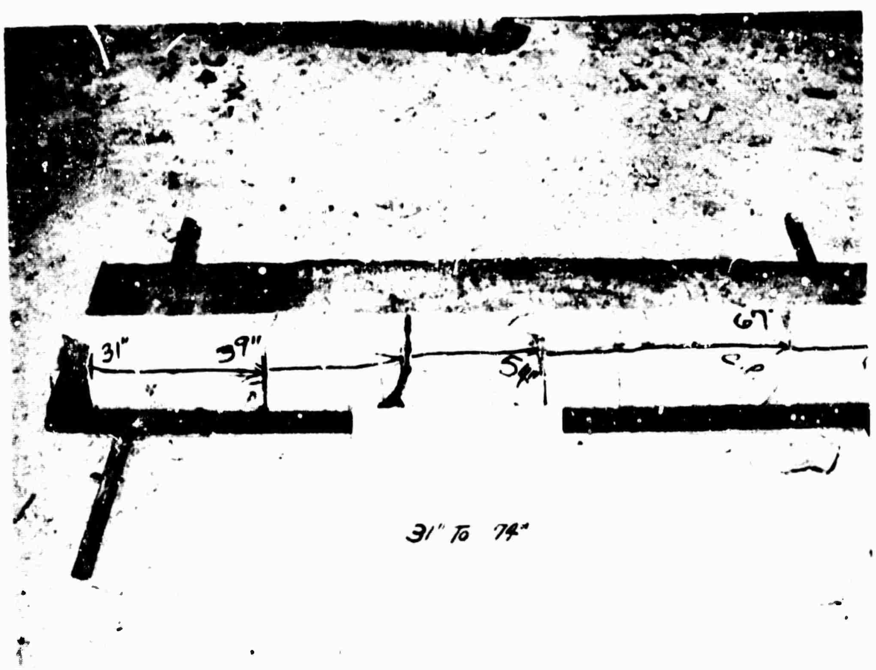


Figure 8b Site 2, Hole 2, interval 31 to 74 inches, core sampling. (DASA 451-12-NTS-62)

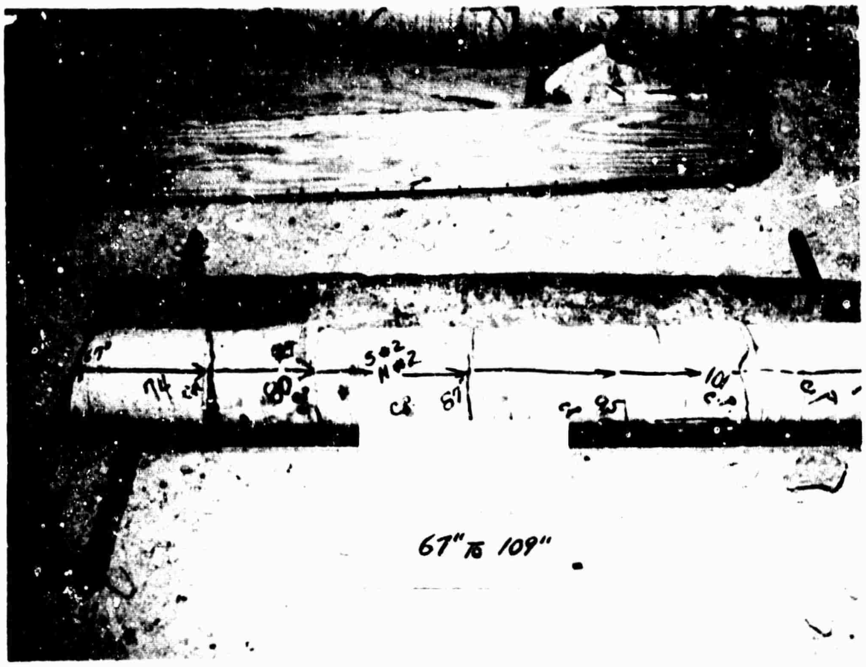


Figure 8c  Site 2, Hole 2, interval 67 to 109 inches, core sampling. (DASA 451-11-NTS-62)

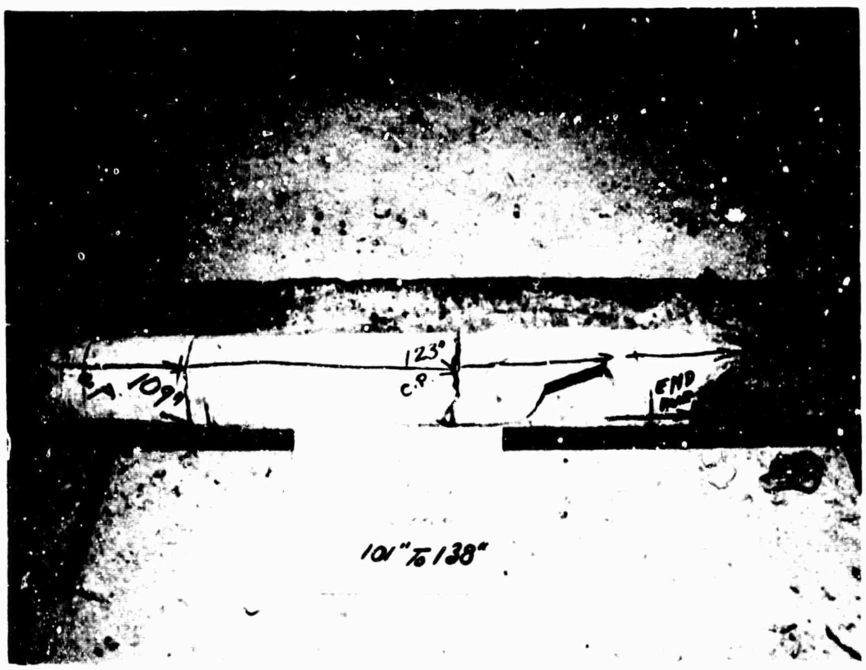


Figure 8d  Site 2, Hole 2, interval 101 to 138 inches, core sampling. (DASA 451-15-NTS-62)


Figure 9a Site 2, Hole 3, interval 0 to 44½ inches, core sampling. (DASA 451-14-NTS-62)

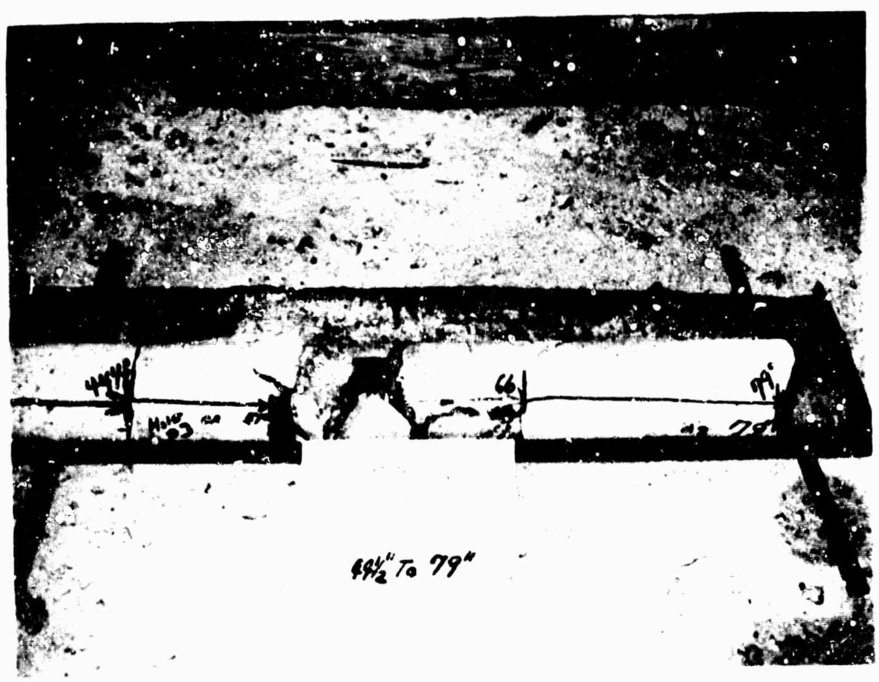


Figure 9b Site 2, Hole 3, interval 44½ to 79 inches, core sampling. (DASA 451-13-NTS-62)

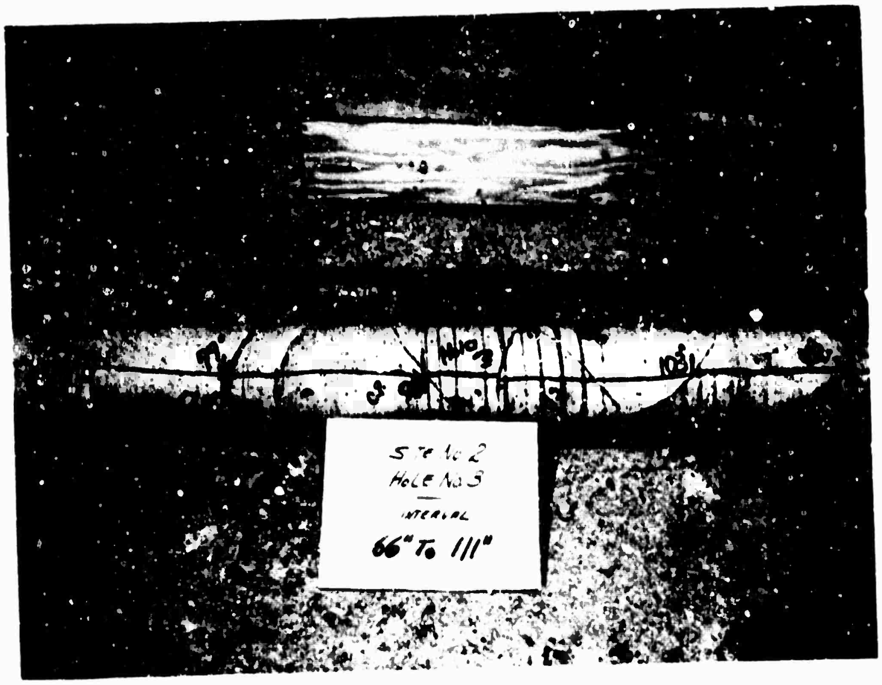


Figure 9c Site 2, Hole 3, interval 66 to 111 inches, core sampling. (DASA 451-18-NTS-62)

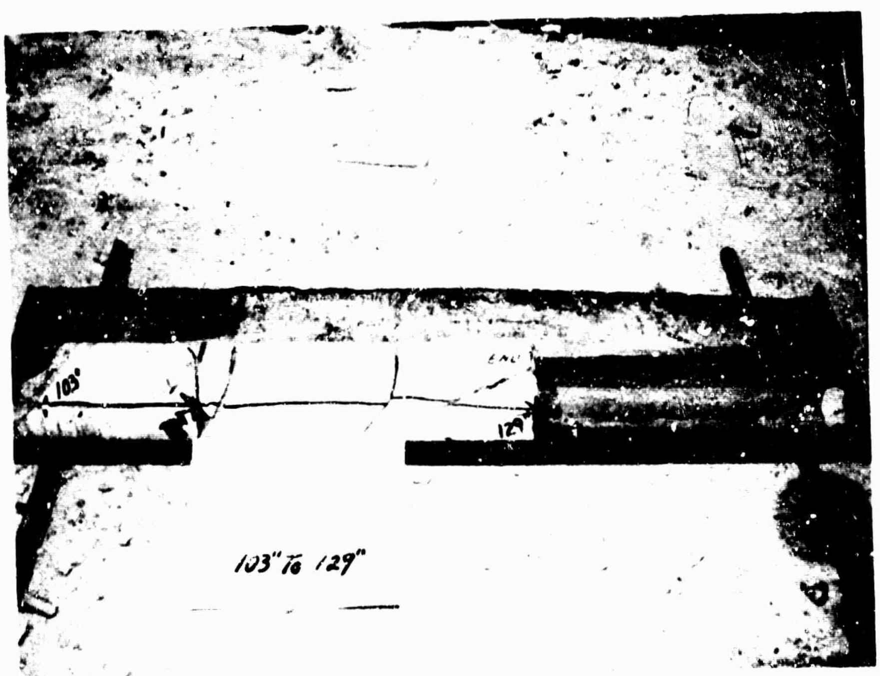


Figure 9d Site 2, Hole 3, interval 103 to 129 inches, core sampling. (DASA 451-17-NTS-62)


Figure 10a Site 2, Hole 4, interval 0 to 37 inches, core sampling. (DASA 451-08-NTS-62)

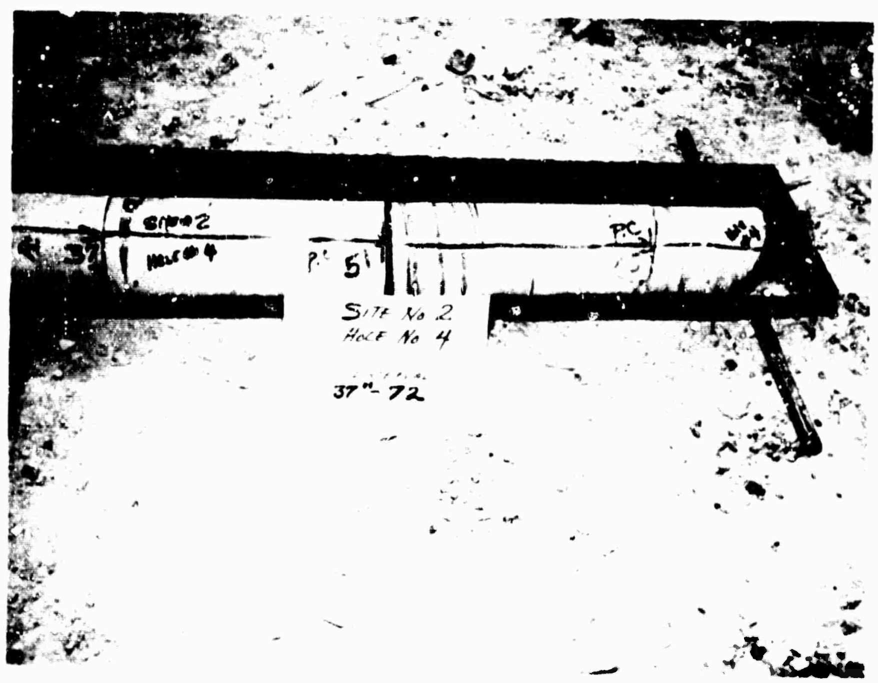


Figure 10b Site 2, Hole 4, interval 37 to 72 inches, core sampling. (DASA 451-10-NTS-62)

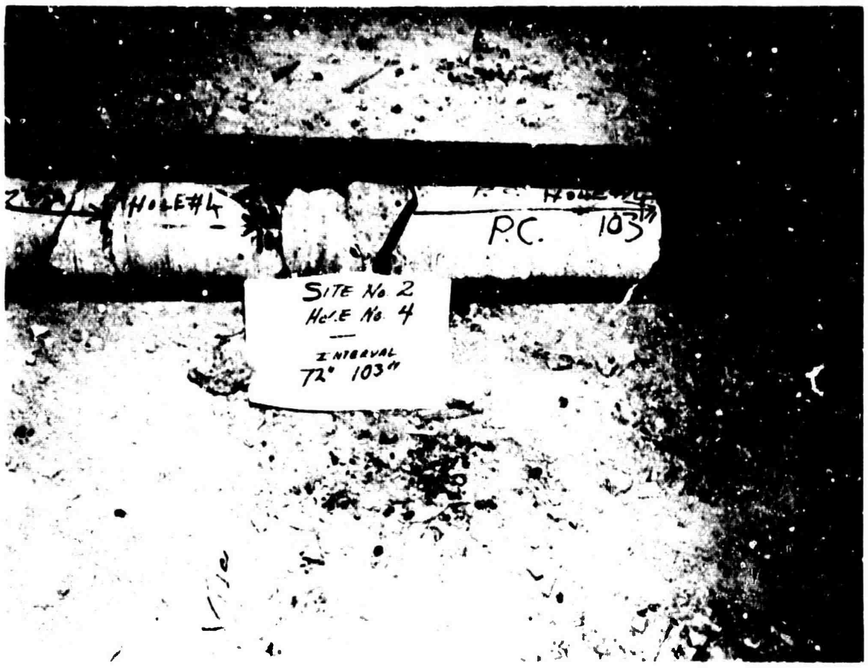


Figure 10c  Site 2, Hole 4, interval 72 to 103 inches, core sampling.  (DASA 451-09-NTS-62)

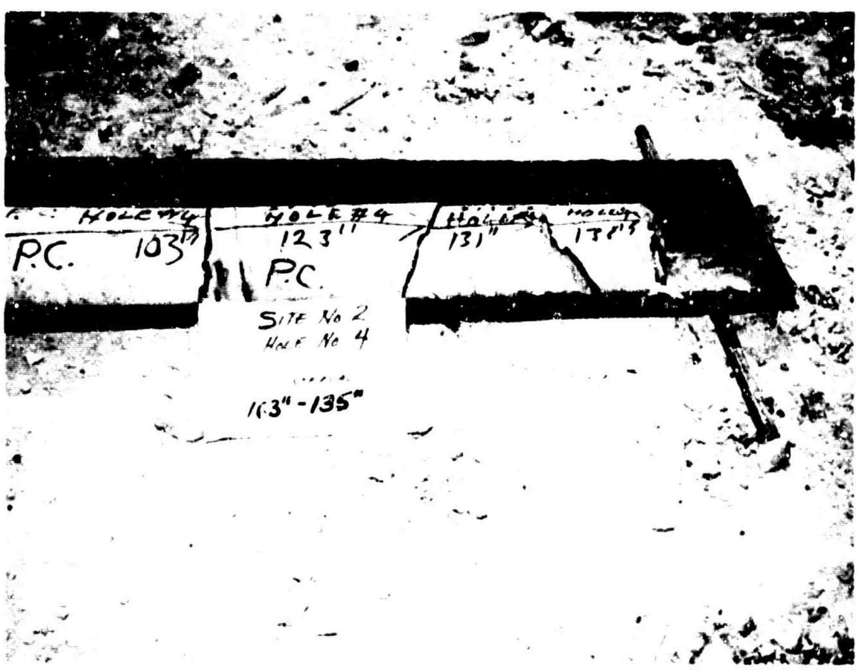


Figure 10d  Site 2, Hole 4, interval 103 to 135 inches, core sampling.  (DASA 451-20-NTS-62)


Figure 10e Site 2, Hole 4, interval 131 to 144 inches, core sampling. (DASA 451-19-NTS-62)

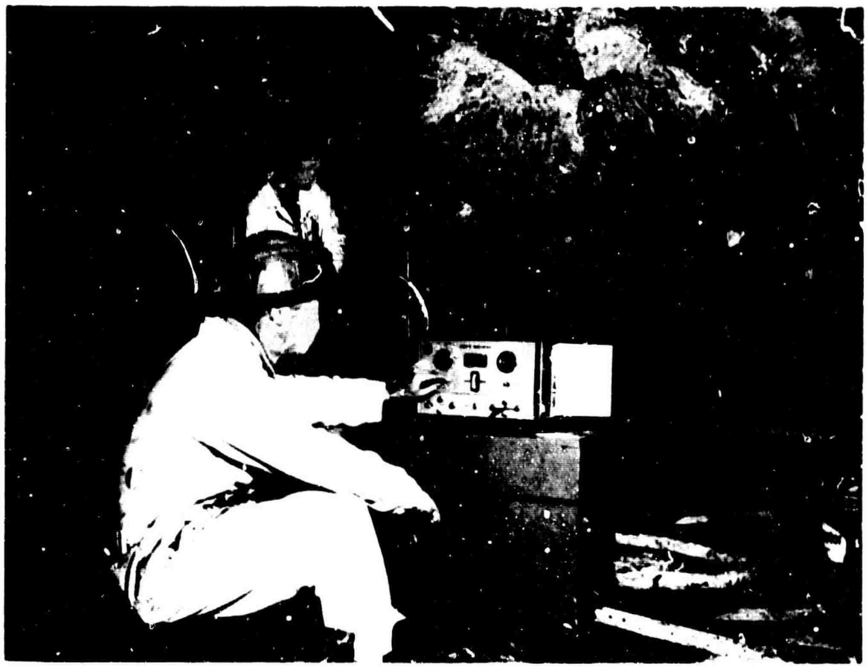

Figure 11 Removal of core sampling from tunnel.
(DASA 387-01-NTS-62)

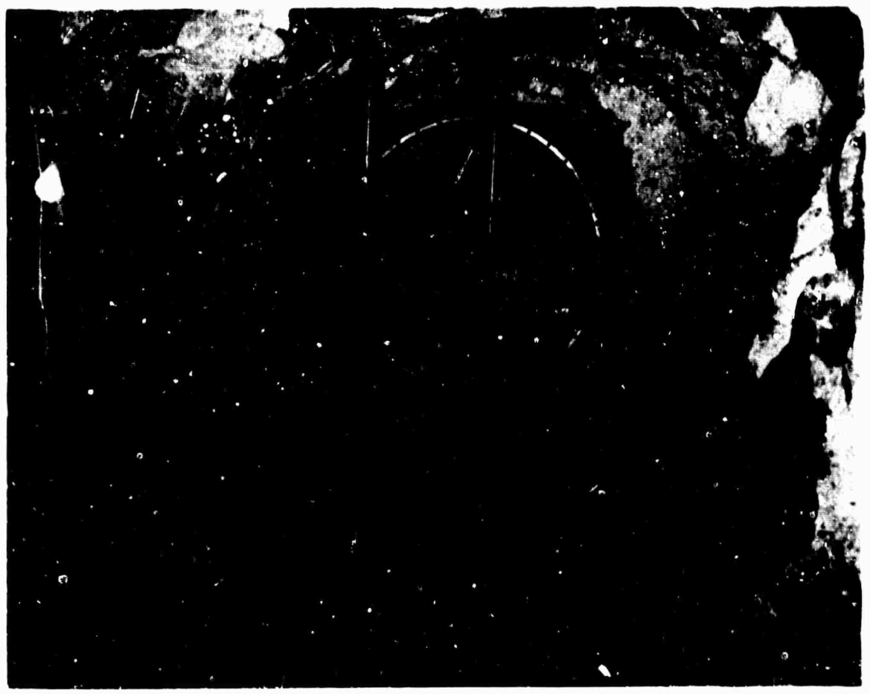

Figure 12 Core sampling to King machine. (DASA 451-05-NTS-62)

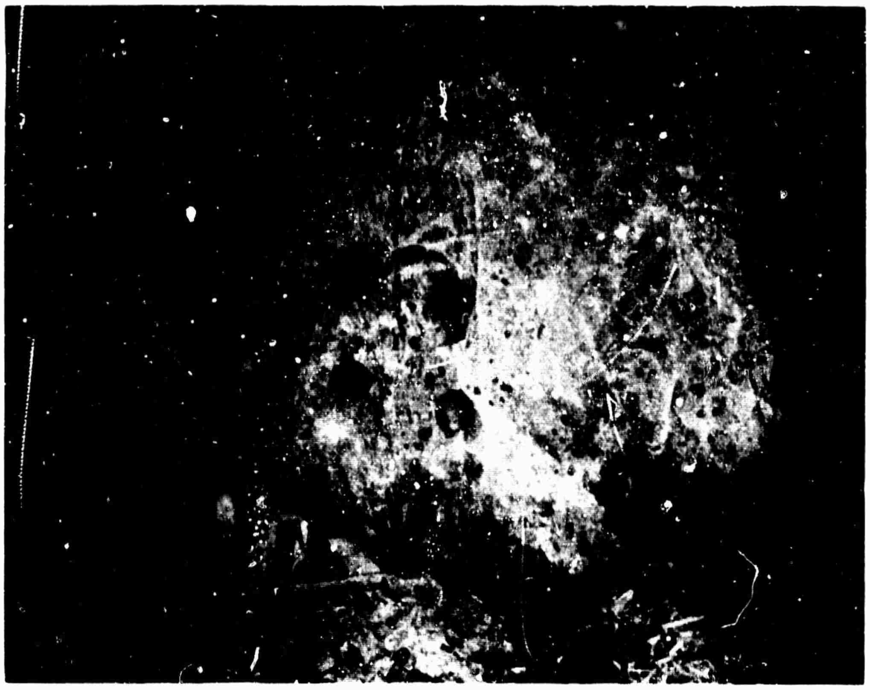

Figure 13 Core sampling holes, at rear of C-drift, right. (DASA 451-03-NTS-62)

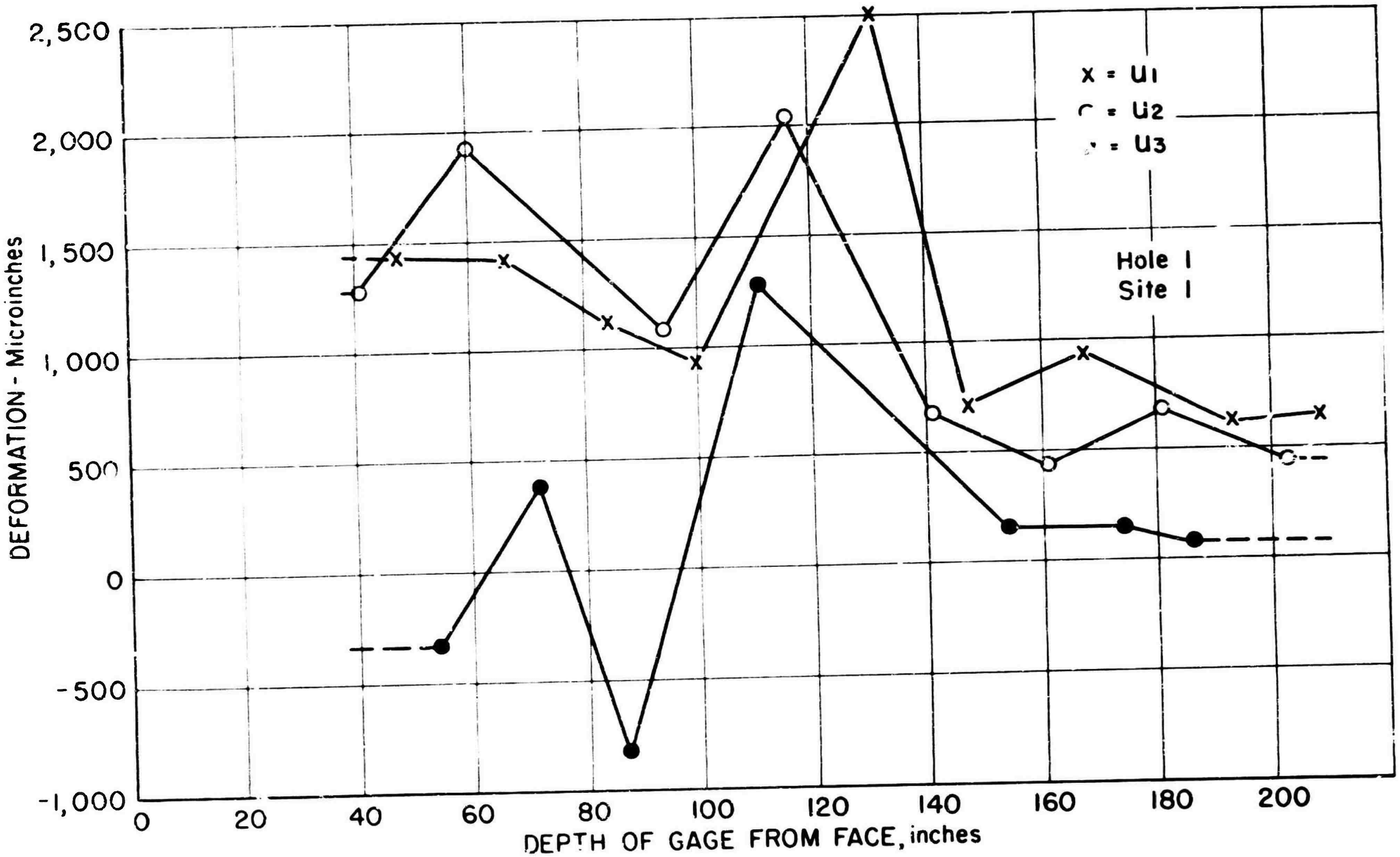


Figure 14 Deformation versus depth of gage, Site 1, Hole 1.

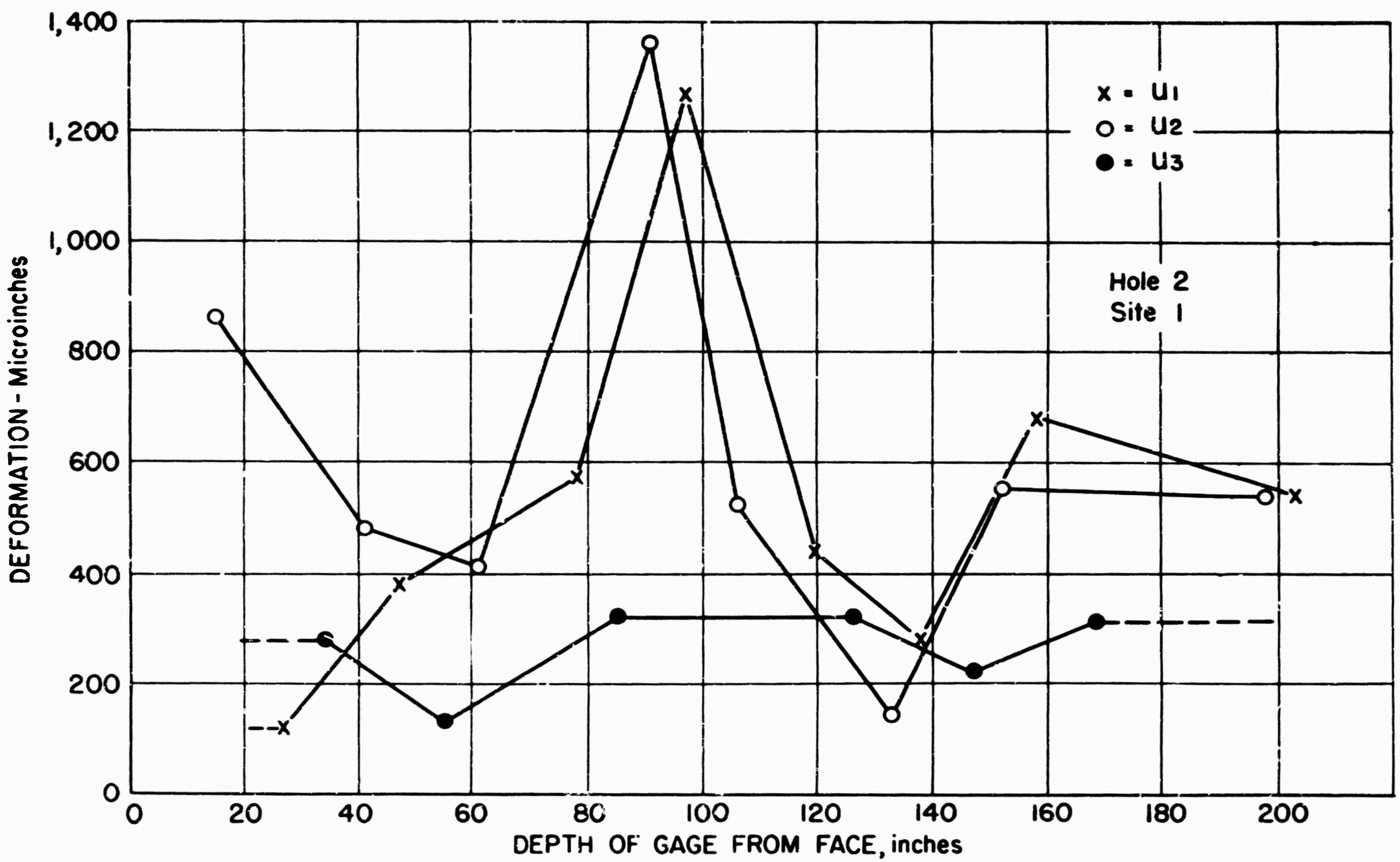


Figure 15 Deformation versus depth of gage, Site 1, Hole 2.

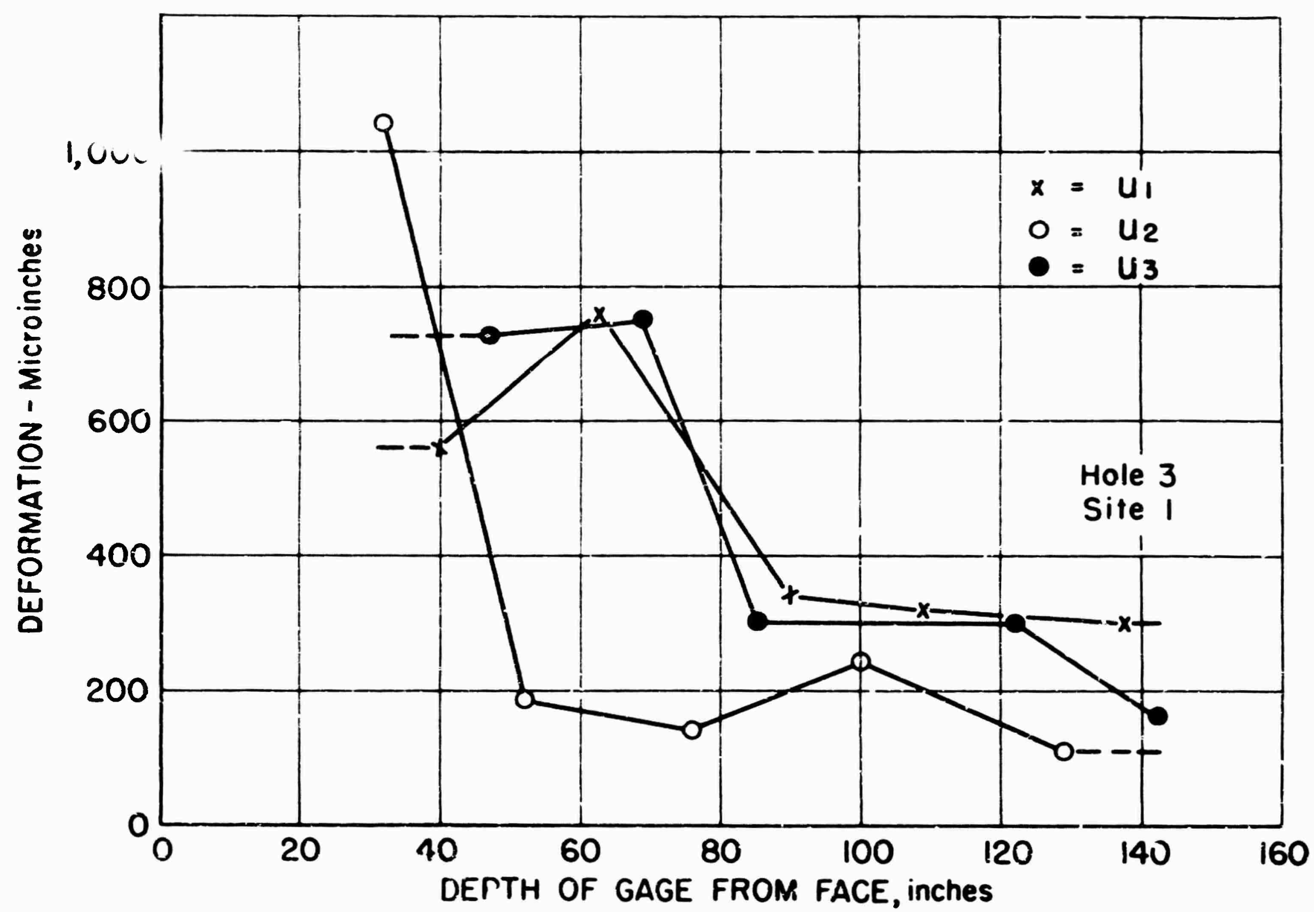


Figure 16 Deformation versus depth of gage, Site 1, Hole 3

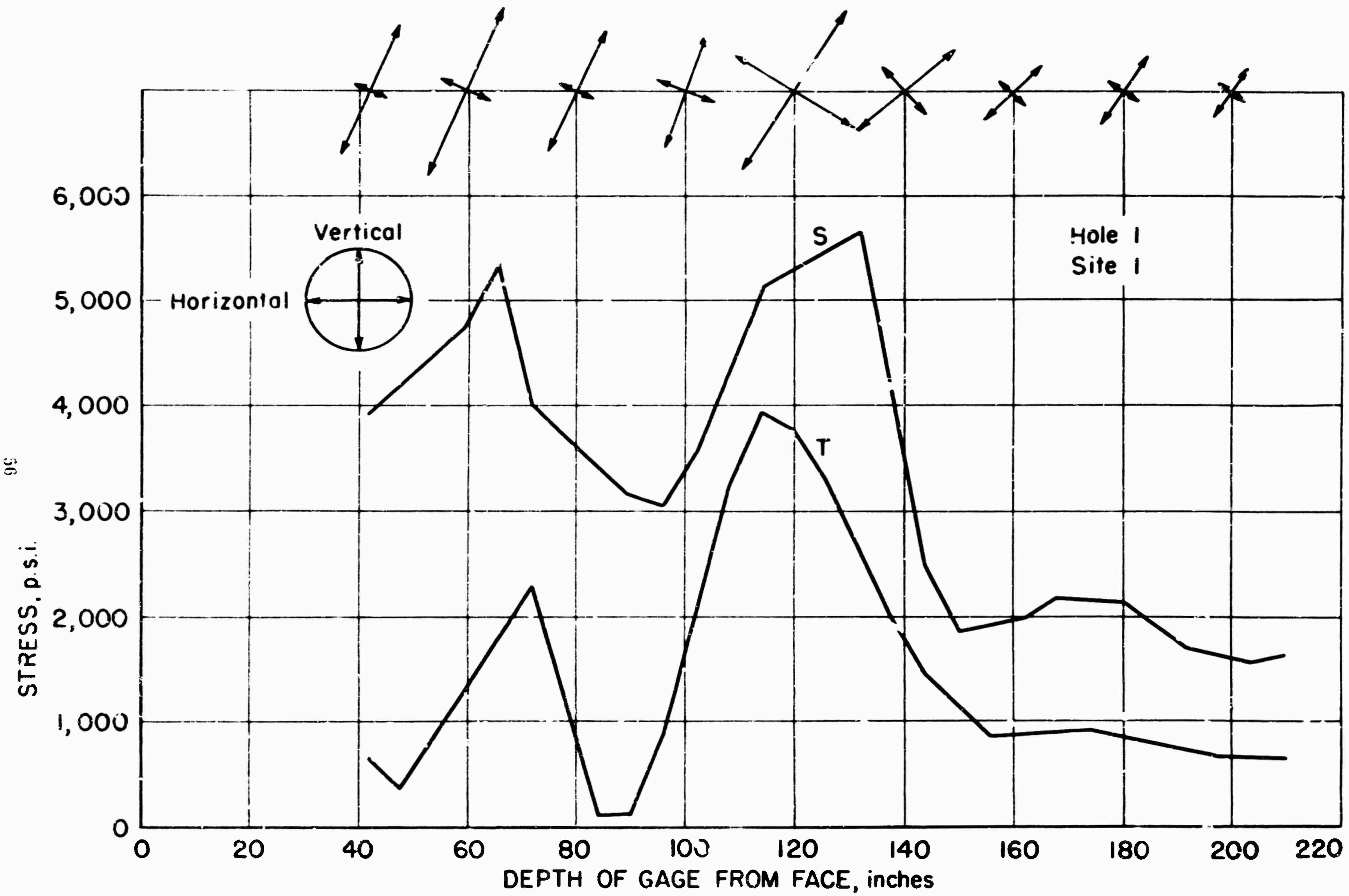


Figure 17 Stress versus depth of gage, Site 1, Hole 1.

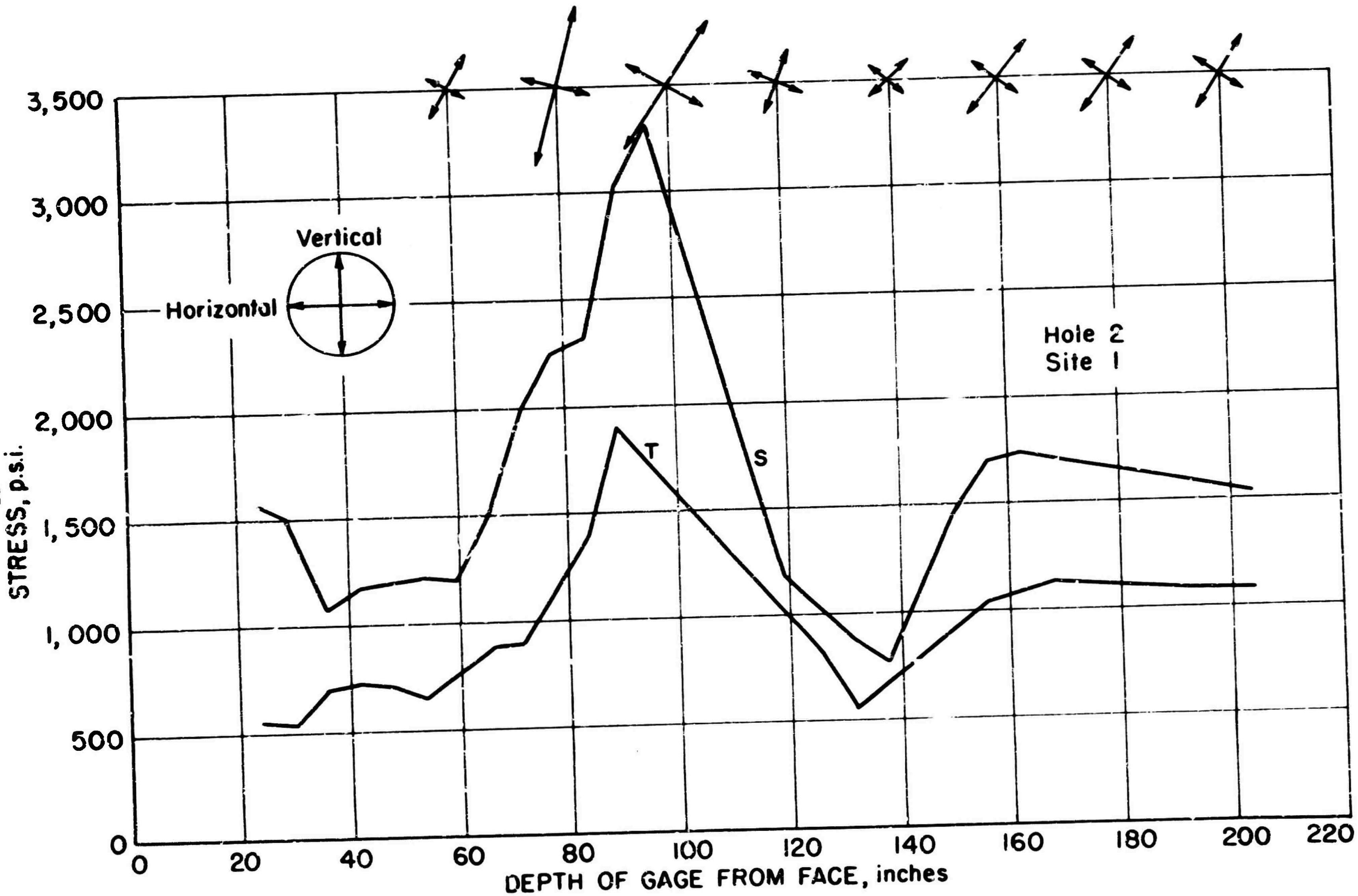


Figure 18 Stress versus depth of gage, Site 1, Hole 2.

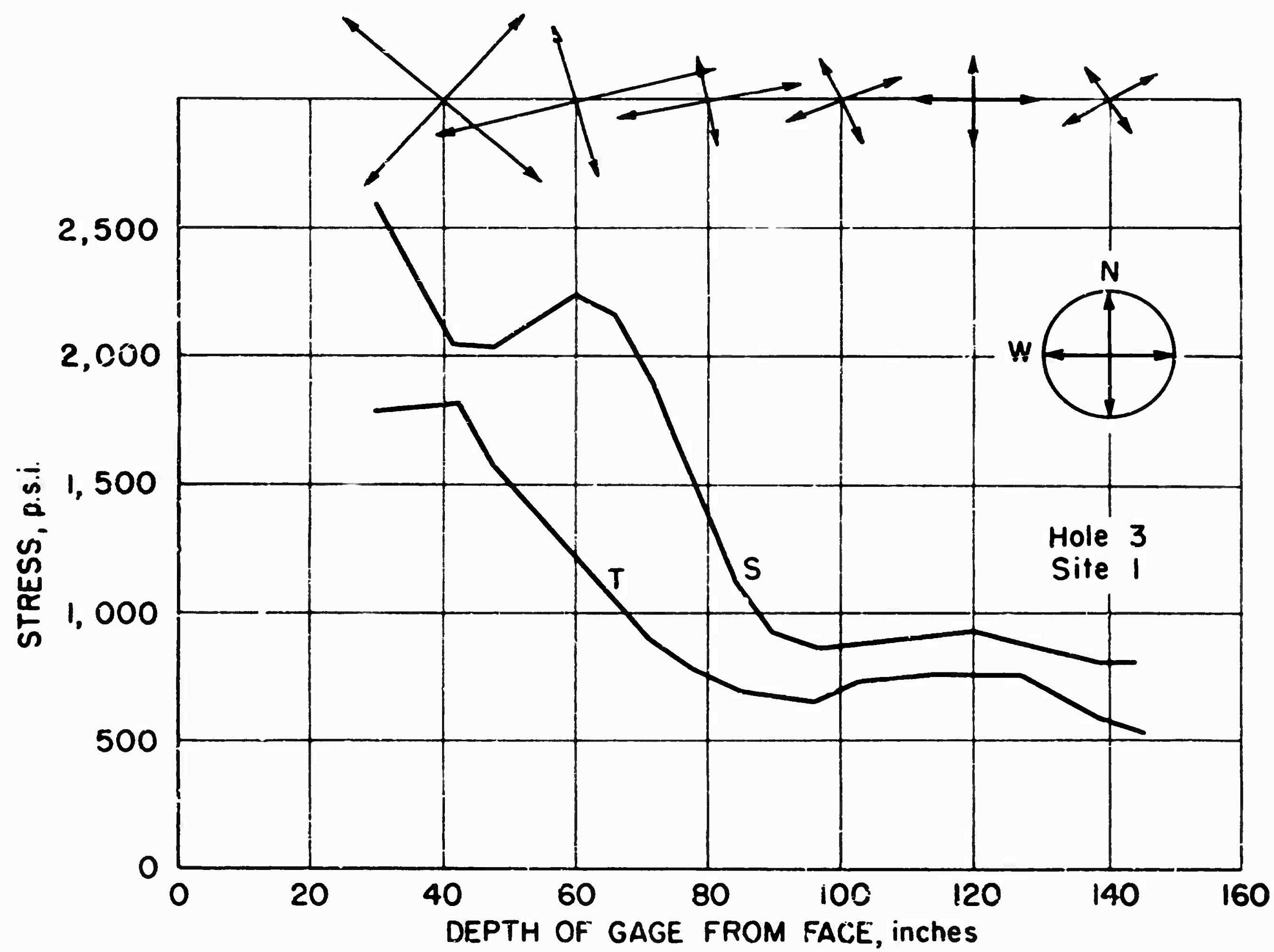


Figure 19 Stress versus depth of gage, Site 1, Hole 3.

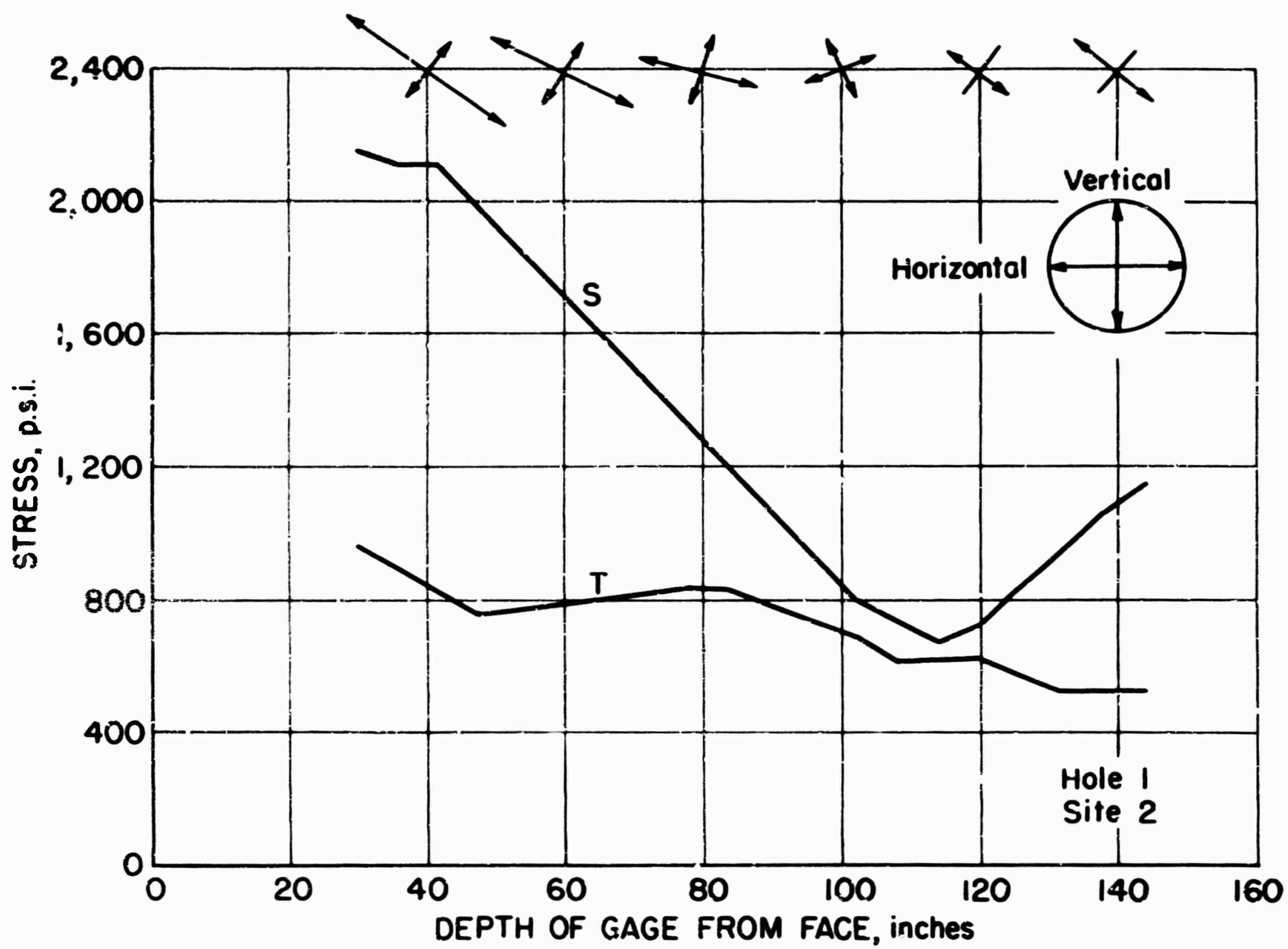


Figure 20 Stress versus depth of gage, Site 2, Hole 1.

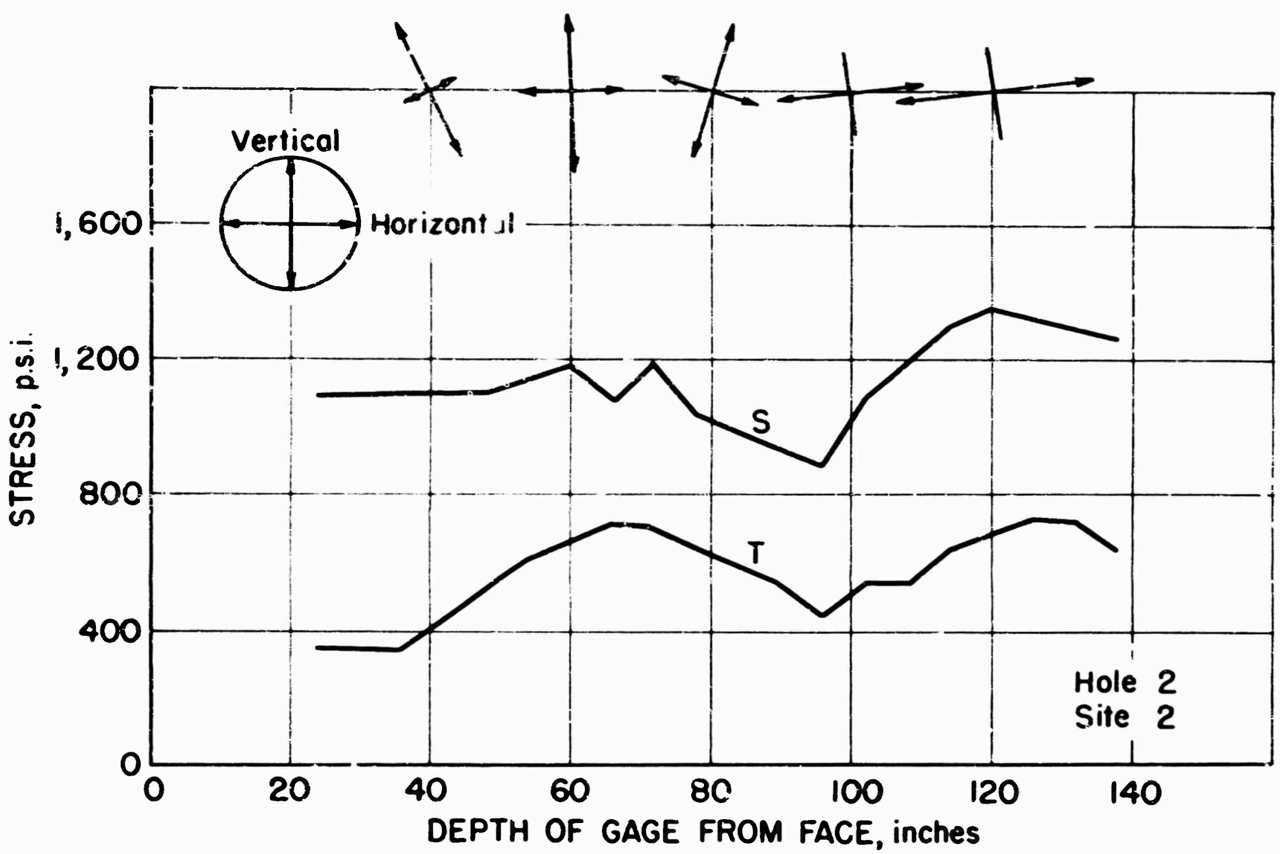


Figure 21 Stress versus depth of gage, Site 2, Hole 2.

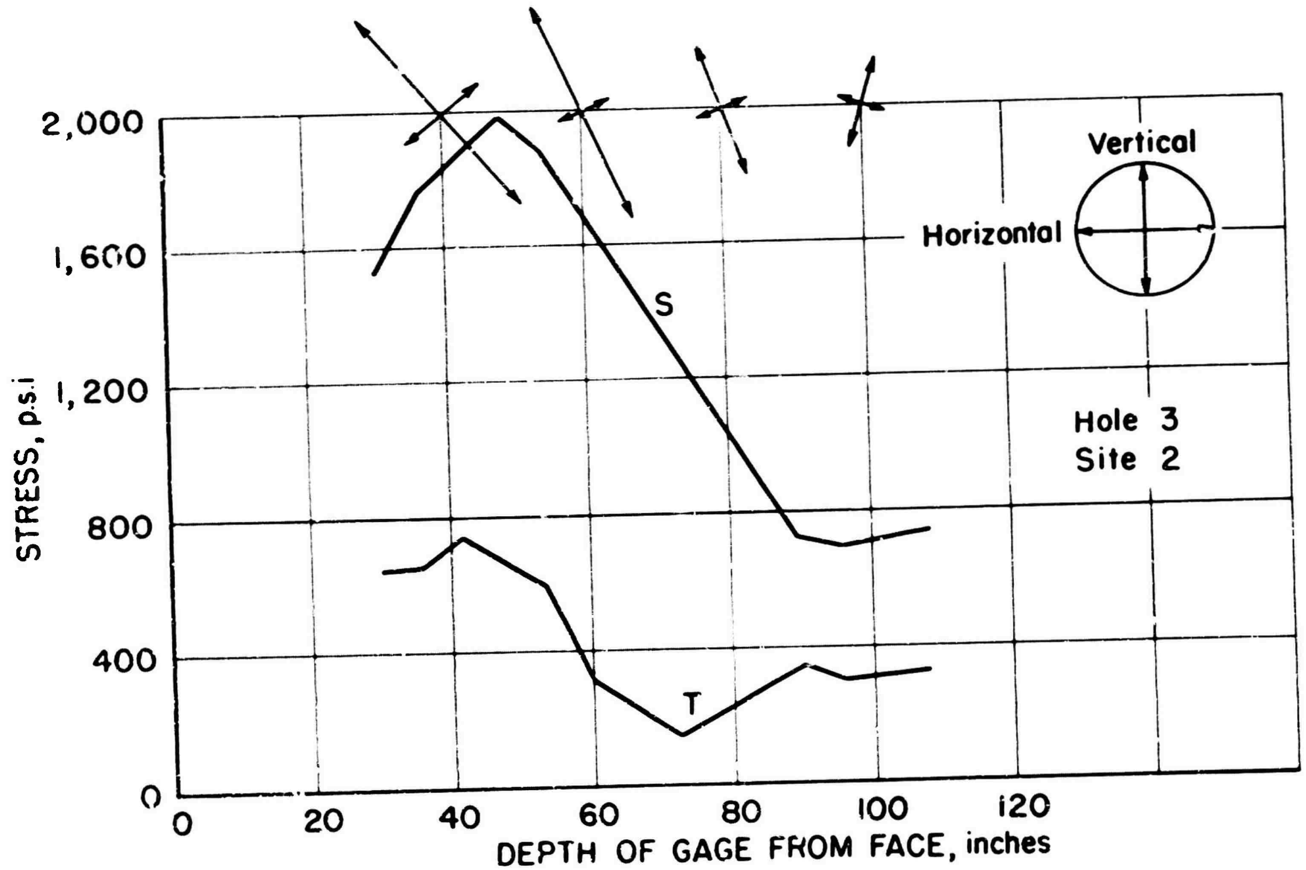


Figure 22 Stress versus depth of gage, Site 2, Hole 3.

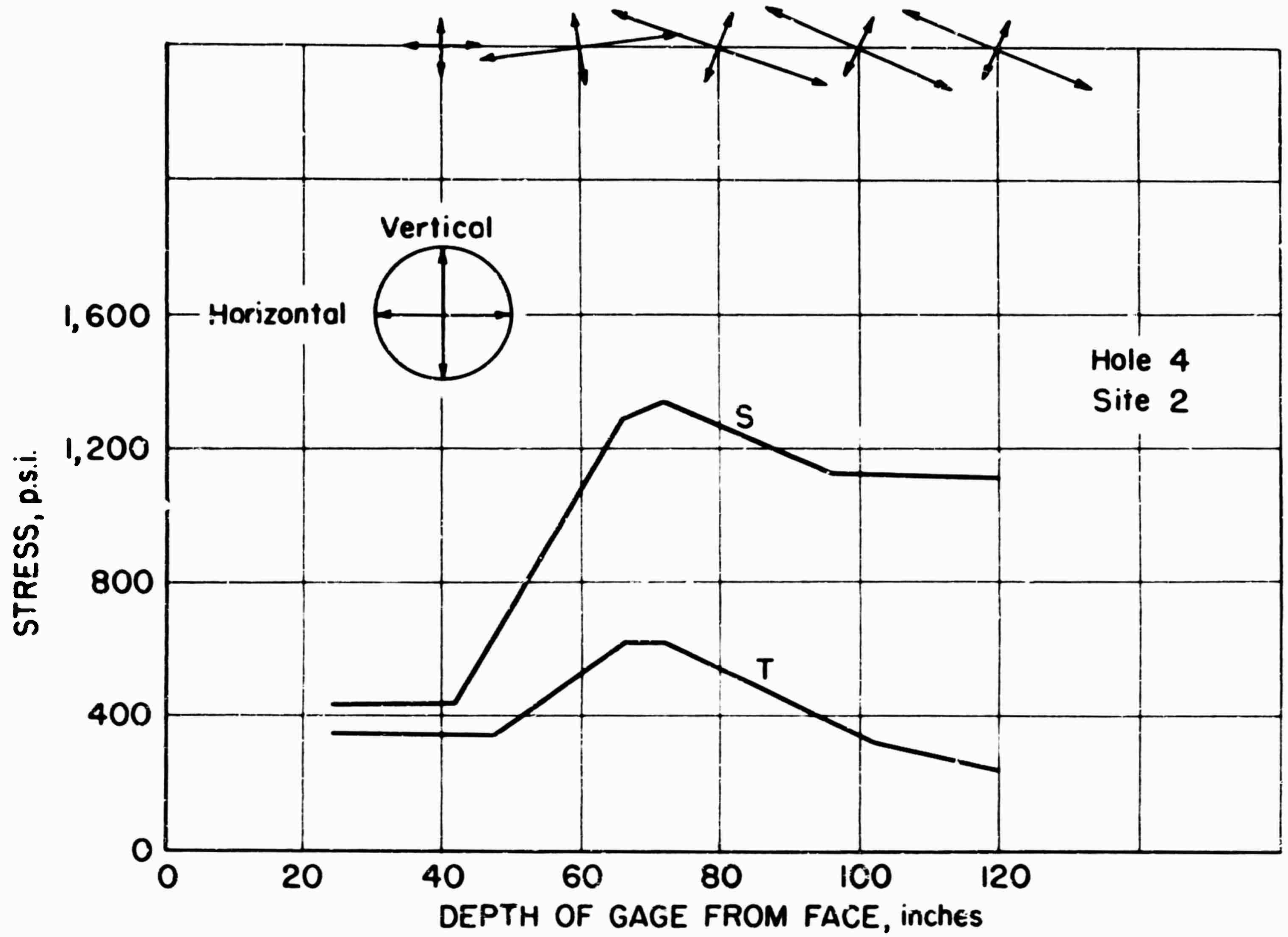


Figure 23 Stress versus depth of gage, Site 2, Hole 4.

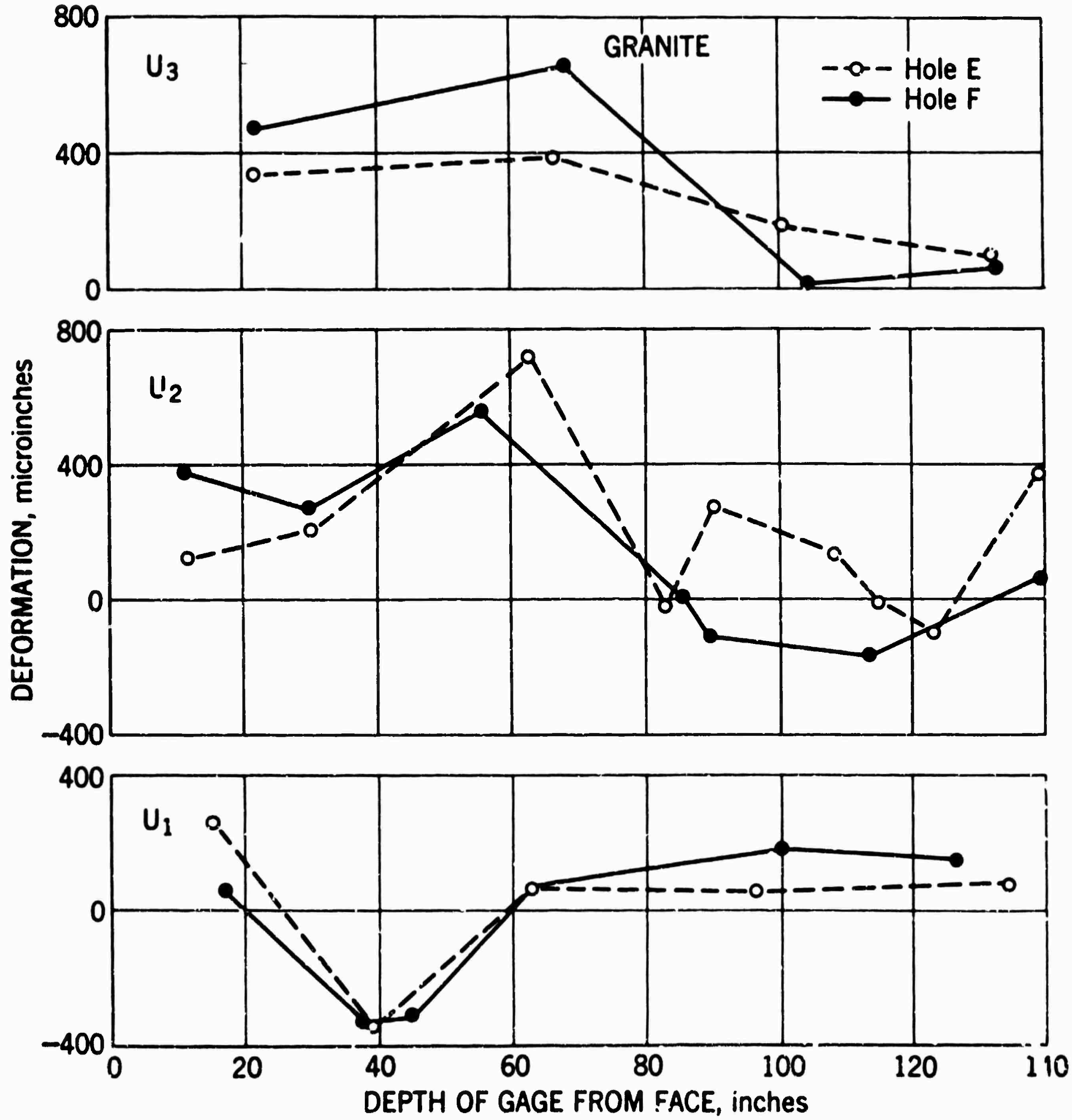


Figure 24 Deformation versus depth of gage, Lollipop, Holes E and F.

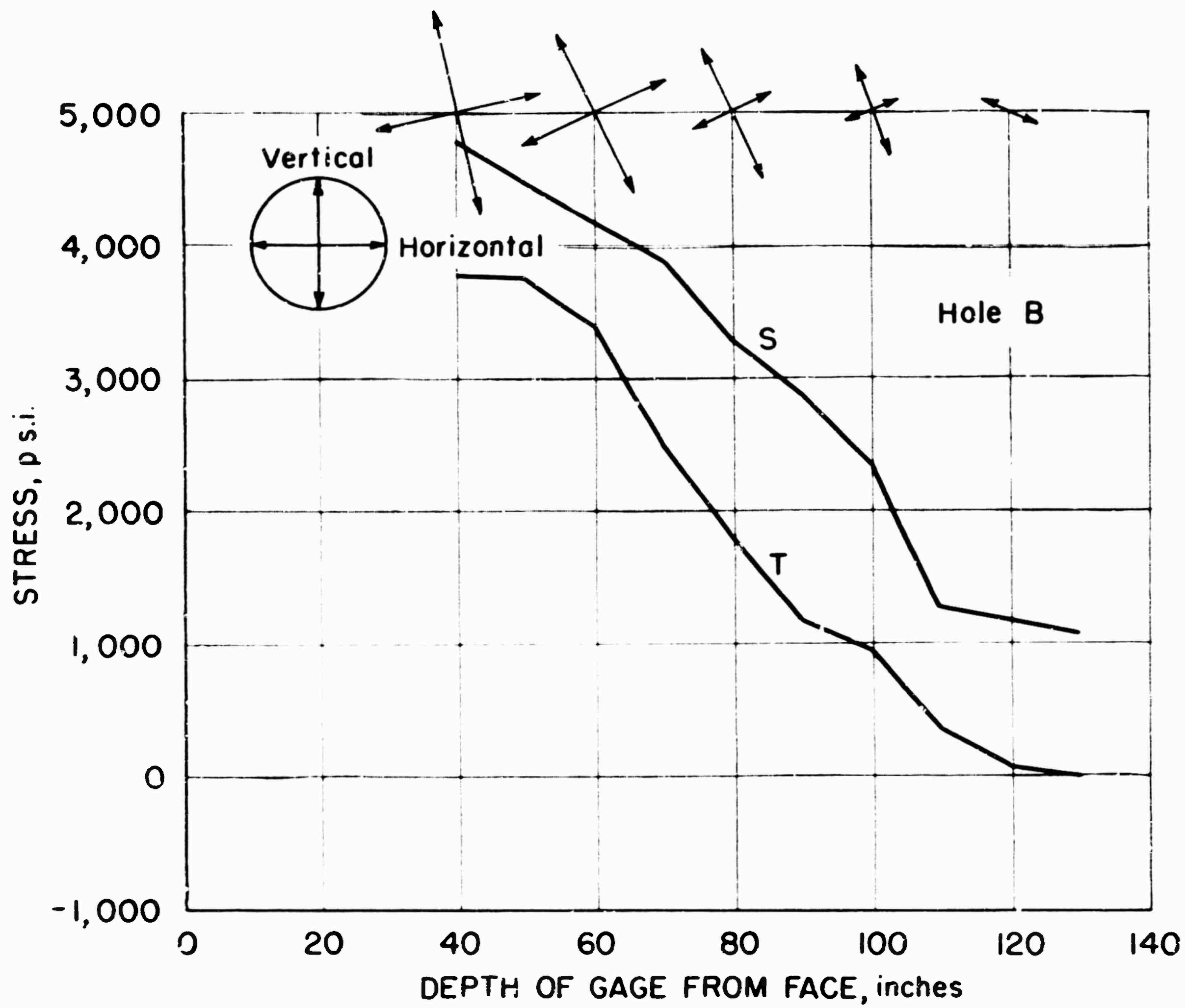


Figure 25 Stress versus depth of gage, Lollipop, Hole B.

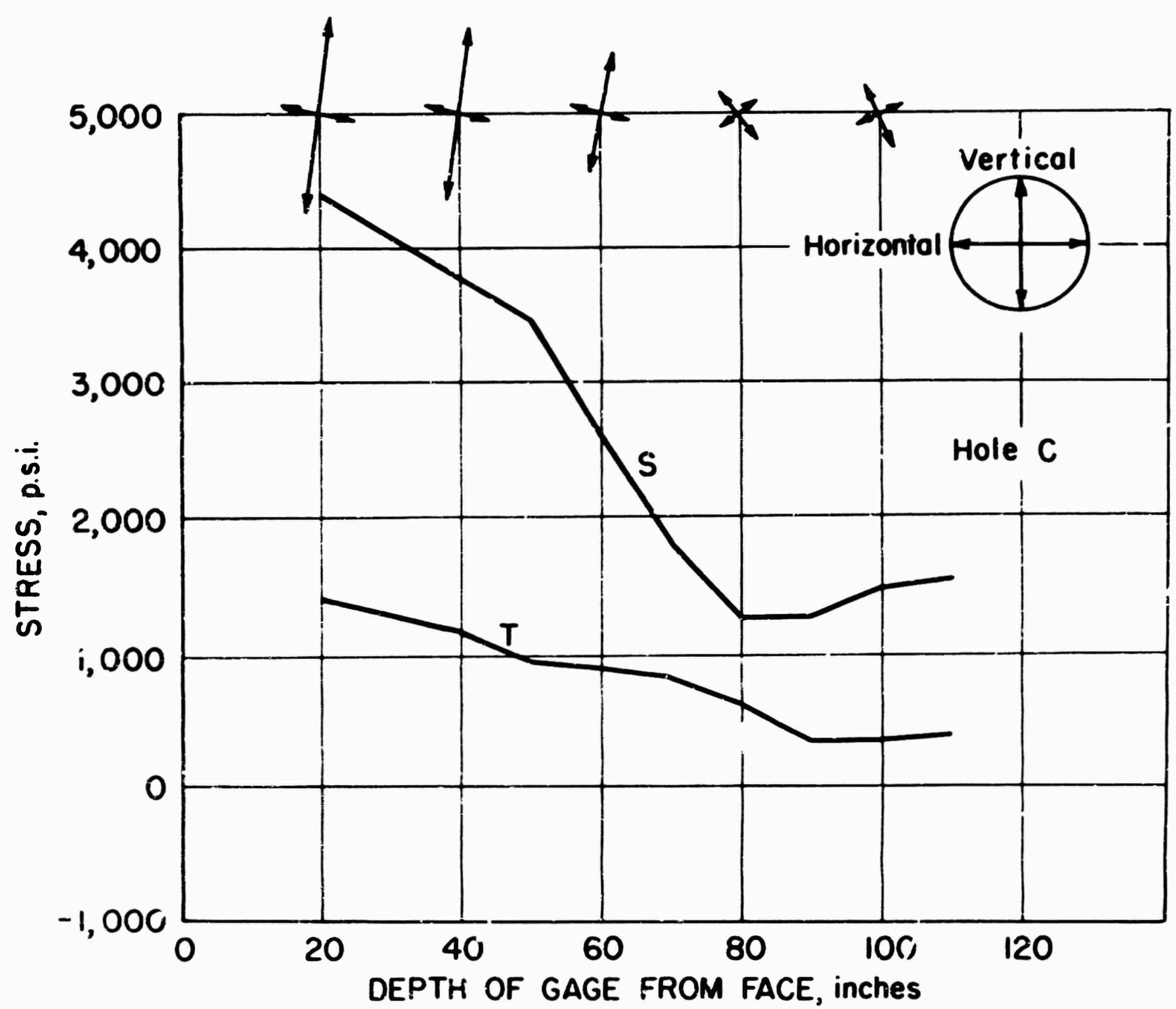


Figure 26 Stress versus depth of gage, Lollipop, Hole C.

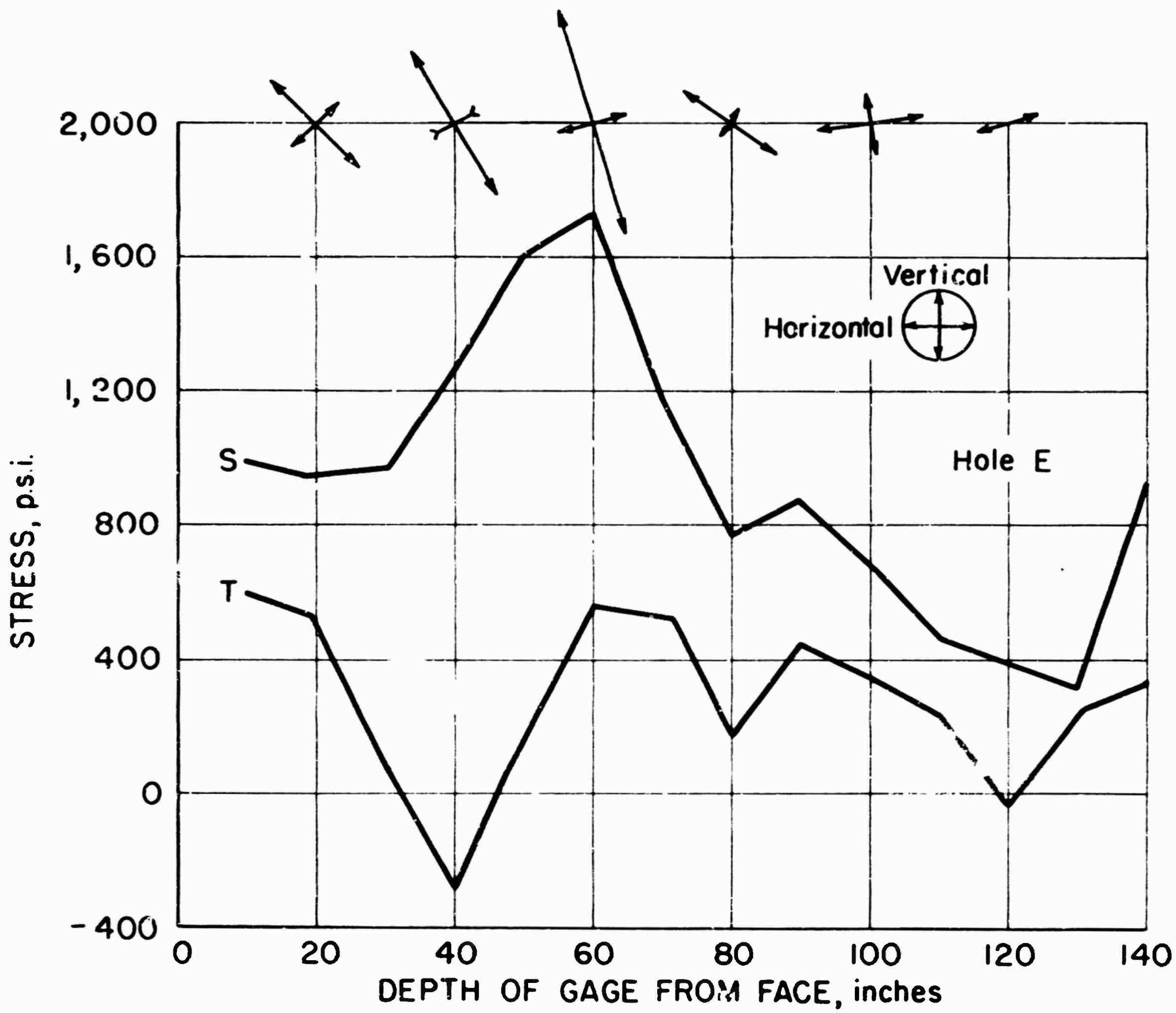


Figure 27 Stress versus depth of gage, Lollipop, Hole E.

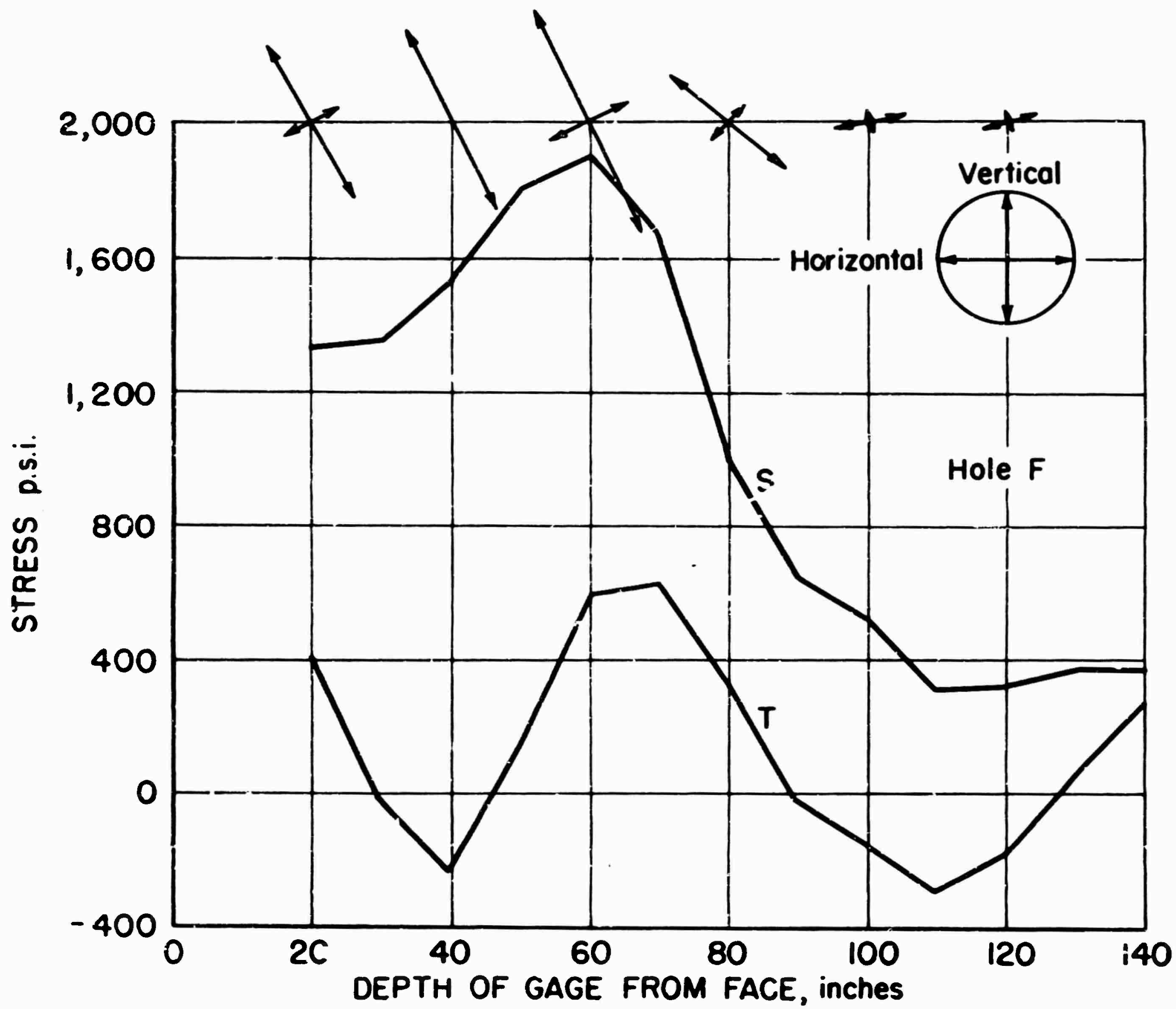


Figure 28 Stress versus depth of gage, Lollipop, Hole F.

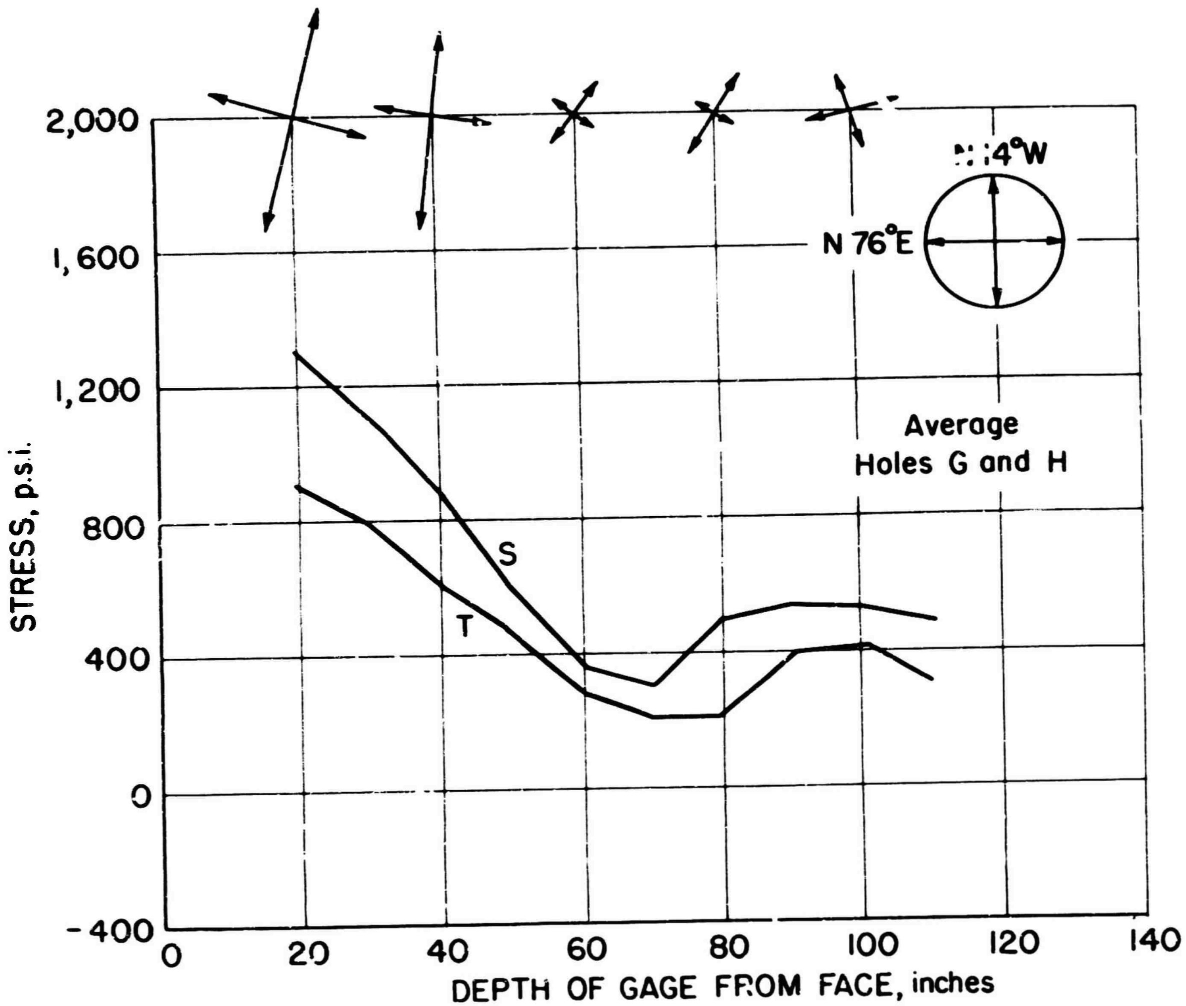


Figure 29 Stress versus depth of gage, Lollipop, Holes G and H.

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